NASA CONTRACT NAS 9-14413

FINAL REPORT

APOLLO EXPERIMENT S-211
LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY

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LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY

Prepared for

Lyndon B. Johnson Space Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Houston, Texas 77058

Robert D. Mercer

Robert D. Mercer
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December 31, 1974

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FOREWORD

This is the Final Report to the Lyndon B. Johnson Space Center, National Aeronautics and Space Administration, under Contract NAS 9-14413 for Apollo Experiment S-211, Low-Brightness, Astronomical Photography. This report has been prepared to satisfy two requirements: to document results of the photographic acquisition of data and analysis of low brightness, astronomical sources, and to present this information in a format suitable for direct publication by the National Space Science Data Center. Principal Investigator for this work has been Mr. Robert D. Mercer of the Institute for Scientific and Space Research, Inc., Delmar, New York. Co-Investigator has been Mr. Lawrence Dunkelman of the Robert H. Goddard Space Flight Center, Greenbelt, Maryland.

The analyses of data on low brightness, astronomical sources are heavily dependent on the technique used in the data collection, in the photometric calibration of the photographic emulsions and in the methods of computer manipulation of this information. These techniques are described, including the equipments used, and examples of results are presented. To facilitate organization of the large quantity of photographs produced and their subsequent processing, detailed listings of descriptive and technical parameters are included as appendices. This also permits an uncluttered presentation of the work, while retaining completeness for future investigators who must rely on these data.

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LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY

INTRODUCTION

The analysis of photography from Apollo lunar flights containing images of low brightness, astronomical sources started in January 1972 as a direct consequence of successful data acquisition efforts sponsored by the National Aeronautics and Space Administration (NASA) and directed by Apollo Program Office's Lunar Orbital Photographic Science Team (APST). Principal Investigator (PI) for the analyses of these data is Mr. Robert D. Mercer, Director of the Institute for Scientific and Space Research, Inc. (ISSR). Co-Investigator (Co-I) is Mr. Lawrence Dunkelman of the Laboratory for Optical Astronomy, NASA Goddard Space Flight Center (GSFC). This work was initiated under NASA Johnson Space Center (JSC) contracts NAS9-12557 to the Dudley Observatory when the PI served there as a Research Associate with the final results reported herein under contract NAS9-14413. In addition, an Intercenter Agreement was used to transfer monies from JSC to GSFC in support of the photodigitization and computer image processing phases of the analysis work.

Astronomical studies on Apollo missions were started in mid-1969 when NASA announced opportunities for investigations to develop maximum scientific return from the remaining lunar flights, once man had landed and safely returned from the moon. These additional studies comprised a very small part of a full program of experiments, most of which pertained to physical measurements of the moon itself. These flights provided new vantage points, quite literally, for certain astronomical observations that could not be duplicated from earth or near-earth orbits. Not only were the geometries uniquely suited to observe interplanetary phenomena, but they also provided the first opportunity to use a celestial body with no atmosphere for observational tasks. Table 1 provides a concise list of opportunities and constraints for such observations. These possibilities were evolved by the APST (Mercer, 1974a) and became companion studies to Experiment S-178, Gegenschein-Moulton Region, with Dunkelman as PI and C.L. Wolff and Mercer as Co-I's. These new studies began to produce useful astronomical photography on Apollo 14 and continued through the remaining lunar missions.

After Apollo 14 -- the first mission in which there was extensive photography from the Command and Service Modules (CSM) with the majority being lunar surface coverage -- data had accumulated sufficiently to warrant a second announcement of opportunity to the scientific community. This was the opportunity to perform analyses on photographs already collected and yet to be collected under APST aegis. In the astronomical field three analytical studies were approved:

S-210 Solar Corona Investigation
PI, Dr. A. Dollfus, and Co-I, Dr. G. Barnet
Observatoire de Paris

S-211 Low Brightness Image Analysis

S-212 Corona Photo Analysis
PI, Dr. R.A. MacQueen
High Altitude Observatory

APOLLO LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY: BACKGROUND

Concept of low brightness, astronomical photography on lunar missions

OPPORTUNITIES

- Spacecraft passes through double umbra
- Atmospheric problems removed - airglow, scattering, extinction, etc.
- Lunar limb occults very close to solar disk
- Operational techniques evolved during Mercury and Gemini missions
- Very high speed films available and space qualified on Gemini missions and Apollo 8 lunar orbital mission
- Fast camera system available on Apollo, 16mm Data Acquisition Camera (DAC) with 18mm, T1 lens
- Large format camera system available, 70mm Hasselblad electric camera (HEC) with 80mm, f/2.8 lens

CONSTRAINTS

- Availability of celestial targets versus sunlight and earthshine
- Requirements on lunar orbital flight trajectory
- Requirements on vehicle attitudes and attitude rates hold limits
- Availability and capabilities of vehicle systems and stowed equipment
- Limitations on crew activities scheduling and time availability
- Higher priority of assigned experiments and other tasks
- Suppression of internal and external light sources from camera optics

Apollo Program's Lunar Science Office establishes Astronomy Working Group under Photo Science Team to recommend tasks

Table 1

While the remainder of this report deals with the second of these, the very close relationship between all of them and formal Experiment S-178 is inescapable. For instance, from Apollo 15 onward all of these experiments depended on the same technique of photometric calibration and very similar operational procedures. Because the S-210 investigators were physically far removed from the daily details, their interests were preserved by coordinated requirements with S-212. Mr. Charles L. Ross of the High Altitude Observatory (HAO) was the chief representative for S-212 and, therefore, also for S-210. Dunkelman and Mercer were members of the APST and Ross was allied with them as a member of the Low Light Level Astronomy Working Group under the APST. All the detailed arrangements for photography as well as scientific and technical inputs for operations and equipment utilization were handled by these three people. For instance, the Command Module Pilot (CMP) and his backup were briefed on the low brightness photography as a single training unit that included the requirements of all four experiments because of their similarity. Facilities at HAO were used extensively by the S-211 and S-178 investigators; also, S-211 often used the facilities of the Laboratory for Optical Astronomy at GSFC. For purposes of historical as well as scientific continuity these interrelationships between experiments will be noted, where appropriate, in text, tables and appendices.

OBJECTIVES

The objectives originally proposed for Experiment S-211 included analyses of low brightness photography covering astronomical sources, planetologic features of the earth and moon, the earth's atmosphere and local contamination of the spacecraft's optical environment. Of these, the astronomical studies were by far the most important, and a detailed description of observational possibilities and constraints is presented in Table 2. The solar corona studies, although specifically assigned to Experiments S-210/212, have been included here because the outer F-Corona, showing the characteristic Fraunhofer absorption line spectra, and the inner zodiacal light are caused by exactly the same physical process, i.e. the scattering of incident sunlight by countless grains of interplanetary dust in heliocentric orbit along or close to the ecliptic (zodiacal) plane of the solar system. These photographic data close to the sun are, therefore, of importance to all three investigations. S-211 analysis relates the inner zodiacal light brightness to that existing both in and out of the ecliptic at greater elongation angles from the sun. S-210/212 analysis relates it to structure and dynamics peculiar to the sun's corona.

The vantage point of low-altitude, lunar orbit was particularly valuable for astronomical studies. The CSM regularly passed through the double umbra, the region behind the moon shielded both from sunlight and from earthshine. This is the darkest region for celestial observations that man has ever reached. Even if the CSM were surrounded by a cloud of effluent particles, these present no problem as long as the material is not illuminated by relatively bright astronomical or spacecraft light sources. It was imperative, therefore, to utilize the scientific advantages provided by the double umbra. Equally important, the atmosphereless, lunar limb, at a distance of infinity with respect to camera focal lengths, provided a perfect occulter for observations right up to the solar disk. Such conditions will not exist until instrumented satellites are again placed in lunar orbit or observing sites put on the far side of the lunar surface. Hence, a long range return from these data will be an early assessment of expected conditions for lunar-based observatories of the future.

APOLLO LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY: SCIENTIFIC OBJECTIVES

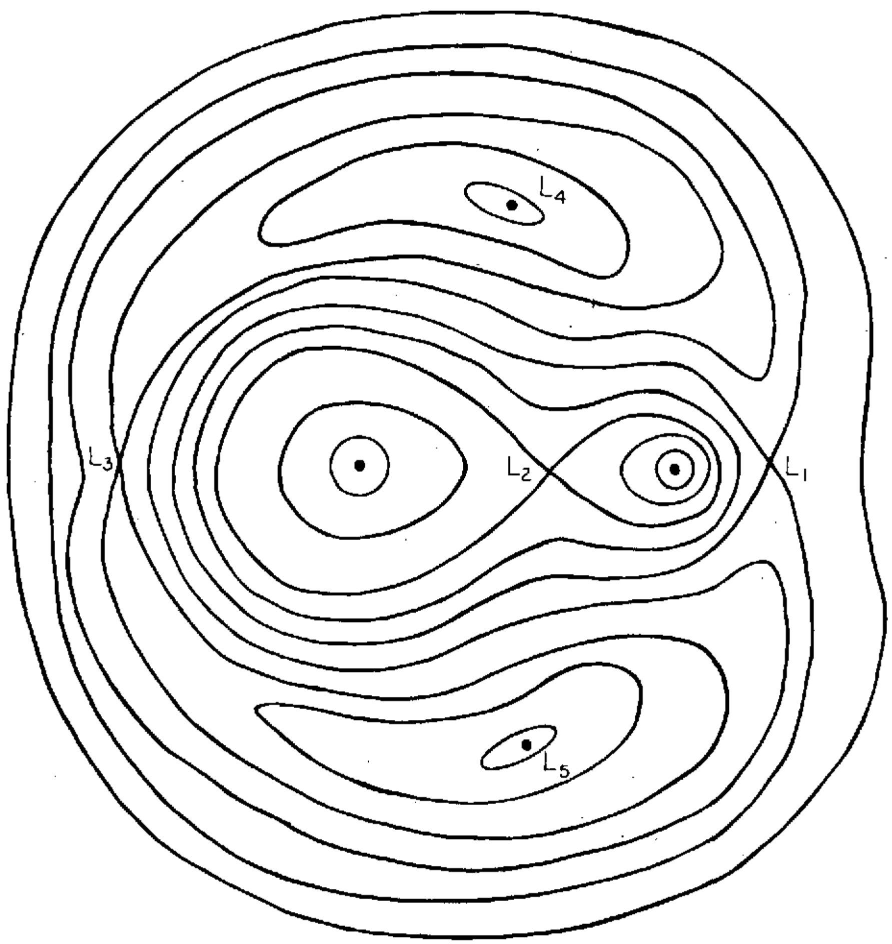
• Solar corona	- Inner coronal structure, morphology and change in appearance with solar rotation
• Zodiacal light	- White light scattering by interplanetary dust to obtain information on particle sizes and their large scale distribution in space
	- Polarized component of white light to obtain information on the optical properties and types of constituent materials for the particles
	- Red versus blue color brightnesses to determine local distributions in particle sizes within the large spatial distribution
• Galactic light	- Detection of halo extensions outward from galaxies to observe structure, and to measure brightnesses and to detect bridging between galaxies
	- Studies of interstellar light from several regions in our Milky Way galaxy
• Lunar libration region L_4	- Diffuse light scattered by the L_4 earth-moon gravipotential holding region which might contain a cloud of trapped particles
• Gum nebula	- Red light emission of $H\alpha$ by pulsar-excited hydrogen gas clouds versus spatial distribution of blue light emission from singly and doubly ionized oxygen clouds
• Earth's darkside	- Lightning pattern distributions
	- Airglow detectability
	- Aurorae detectability
• Special opportunities	- Studies of diffuse cometary brightness around nucleus, and studies of gas and dust components in comet's tail
	- Eclipsed moon's disk brightness and color in umbra due to sunlight scattered by earth's atmosphere
	- Sun eclipsed by earth to obtain baseline data on planetary atmospheres and eclipsed by moon to obtain further information on solar corona

Table 2

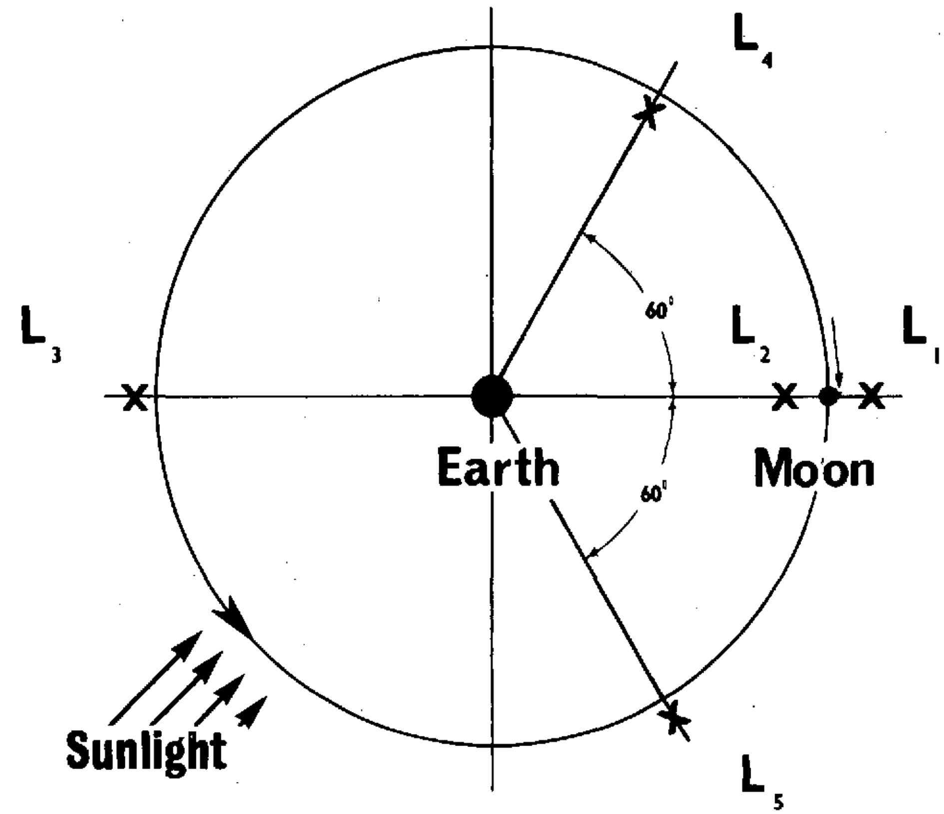
Zodiacal light, gegenschein, Moulton region and the lunar libration regions that proceed ahead of and behind the moon in its orbit are positions of actual or suspected concentrations of interplanetary dust particles ranging in size from tens to tenths of a micron. They are mainly thought to be the residue of unaccreted, solid materials left behind with the planets as a protostar contracted into our solar system. As such, they lie near the ecliptic plane or lunar planes of the planets. They are under the general influence of the sun's gravitational field, but are perturbed by gravitational attractions of nearby planets and their moons. If close enough, such particles may also be locked into planetary or lunar orbits as well. Because these planetary-lunar subsystem of gravitational forces are imbedded in the solar force field, regions of dust concentration and avoidance can form, providing specific subjects for photographic analyses. Discovery of the exact locations for these accumulations, and measurements of their brightnesses over foreground or background light levels is the fundamental purpose of these analyses.

Mathematical models of the restricted three-body problem began with Lagrange just over two hundred years ago. It was independently solved by Jacobi seventy years later, and improved upon by Hill, Poincare and George Darwin for the case where one of the three masses is infinitesimal compared to the others. The classical reference is by Moulton (1914). Figure 1 shows on the left a family of curves of constant gravipotential energy in the plane of lunar orbit. The three crossover points L_1, L_2 and L_3 are unstable points of zero relative velocity for a small particle with respect to the large masses. L_4 and L_5 are the stable, zero relative velocity points. These theoretical points where dust particles having the proper initial conditions of motion might linger (Michael, 1963) are shown on the right of Figure 1 for the specific lighting and geometry that existed during Apollo 15. It shows, for instance, how the L_4 region could be observed from the double umbra while L_5 could not. Also the slight shift in L_4 and L_5 towards the positions of the sun and Jupiter indicates schematically how perturbations further complicate the elegant theoretical picture on the left. But there are even further complications caused by rotating masses (Allan, 1966), and the dynamics problems from non-gravitational force fields such as solar photon pressure, Poynting-Robertson drag effect, and even electric and magnetic forces, especially in the corona, if the dust particles possess electric charge. Beyond this, there must be consideration for the geometrical aspects of light scattering by the particles (van de Hulst, 1957) to determine if the particle densities are truly non-uniform as suggested theoretically for regions of accumulation or only appear so because of optical properties of enhancement, such as strong backscatter in the zodiacal light producing the gegenschein.

APST planning of astronomical tasks included photography of extended regions just beyond the perceptible boundaries of individual and clustered galaxies. It was hoped also that connecting bridges of faintly glowing material between galaxies might be observed, supporting new theories on galactic formation (Arp and Bertola, 1971). In addition, recent studies of the Gum nebula (Maran et al, 1971) indicated that very faint nebulosities, with the southern Milky Way as a complicating background, might actually be the shock-front remnant of a nearby supernova. This phenomenon was a particularly appealing subject to be photographed from the double umbra because it was very faint and covered a large field more suited to camera optics than to the narrow fields of earth-based telescopes below the airglow layer.



RESTRICTED THREE-BODY PROBLEM FORCE FIELD CONTOURS ON SMALL MASS



APOLLO 15 EARTH-MOON GEOMETRY SHOWING THE SUNLIGHTING AND REGION OF DOUBLE UMBRA

Figure 1

Objectives in planetology, the earth's upper atmosphere and contamination were only to be pursued if such data were present on the photography and not specifically assigned to other investigators. Low brightness photographic analyses of the lunar surface near the terminator and in earthshine were assigned to others, as was a contamination study. Earth planetologic and atmospheric studies were included in the event the lunar portion of any mission had to be aborted but earth orbital flight could continue; however, this situation never occurred.

PHOTOGRAPHIC EQUIPMENT

In order to collect all of the available light from low brightness sources, it was necessary to choose flight-qualified camera systems with the fastest lenses, i.e. largest aperture-to-focal-length ratio, and the most sensitive emulsion available. But this alone was not enough, and every data frame required time exposure for tens, even hundreds of seconds, except for a few obtained just prior to sunrise. The Eastman Kodak type 2485 high-speed, black-and-white, recording emulsion (Eastman-Kodak, 1967) performed very well. However, it does exact a price for its high speed, producing large grain structure at very low light levels. So, the largest camera formats available were used to reduce the scale of grain noise on the celestial scene when such choice was not unduly offset by a loss in lens speed. The 16mm format Data Acquisition Camera (DAC) with 18mm, T1 lens was used on Apollo 14, but the 35mm Nikon (NK) with f/1.2 lens, made available to meet requirements of Experiment S-178, was utilized as soon as it became available for Apollo 15 and subsequent flights. Where large fields-of-view were required to cover the scientific phenomenon, the 70mm Hasselblad electric camera (HEC) with 80mm, f/2.8 lens was used, again provided the slower lens speed could be traded against a brighter source, as in the case of the inner zodiacal light/outer solar corona region. Color and polaroid filters were used sparingly, because of their reduction in the speed factor, and only when the phenomenon had previously been photographed in white light, or when absolutely necessary to distinguish it from a strong white-light background. Detailed specifications on all three camera systems and supporting equipments have been documented by NASA (MSC-07210, 1972), although sizes of fields-of-view are not correctly reported for some lenses in that report Correct values for length, width and diagonal of images versus lens are noted in Table 3.

16mm Data Acquisition Camera

The 16mm DAC with 18mm, T1 lens was successfully used on the Apollo 14 mission, although resulting grain structure in the fast film was large. The "T1" refers to f-number, i.e. focal-length-to-aperture ratio, divided by transmission factor for the lens, and in this case both the f-number and transmission are 0.95. The type 2485 emulsion was carried in 140-foot film magazines each of which held about 5500 frames. In order to protect data frames from high light levels, i.e. sunlight leaking past the shutter or film exposed directly to the cabin light environment during magazine removal, the film was advanced twenty frames immediately before and after data collection to create a six-inch buffer on each end of data sets. This completely cleared out film of unknown exposure from the image plane/advance mechanism portion of the magazine and assured that the data frames had come from the protected supply spool and had

SUMMARY OF TASKS AND EQUIPMENT/EMULSION UTILIZATION FOR LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY

Low Brightness, Astronomical Source	AS Flt 14	AS Flt 15	AS Flt 16	AS Flt 17	Camera & Frmt	Lns FL & f/No	Fields-of-View Lngth	Fields-of-View Width	Fields-of-View Diagl	EK Emulsion Type	EK Emulsion Numbr	No. of Data Frames	SprtEquip Br	SprtEquip RM	SprtEquip Sh	SprtEquip PC	SprtEquip RC	Exper No. 211	Exper No. 178	Exper No. 210 212
Zodiacal Light																				
Eastward Elongation																				
White Light	X				DAC 16	18,.95	32.6°	23.4°	39.2°	2485	26-1	32	X	X		X	X	X		
		X			NK 35	55,1.2	35.5°	24.0°	42.9°	2485	101-1	23	X		X			X		
Polarized Light			X		NK 35	55,1.2	35.5°	24.0°	42.9°	2485	107-2	25	X					X		
				X	NK 35	55,1.2	35.5°	24.0°	42.9°	2485	108-1	22	X					X		
Red Light (610-700nm)				X	NK 35	55,1.2	35.5°	24.0°	42.9°	2485	108-1	11	X		X			X		
Blue Light (420-510nm)				X	NK 35	55,1.2	35.5°	24.0°	42.9°	2485	108-1	11	X		X			X		
North Ecliptic Pole	X				DAC 16	18,.95	32.6°	23.4°	39.2°	2485	26-1	5	X	X		X	X	X		
Galactic Light																				
Milky Way		X			NK 35	55,1.2	35.5°	24.0°	42.9°	2485	101-1	14	X		X			X		
Galactic Pole	X				DAC 16	18,.95	32.6°	23.4°	39.2°	2485	26-1	8	X	X		X	X	X		
Other Galaxies			X		NK 35	55,1.2	35.5°	24.0°	42.9°	2485	107-2	2	X		X			X		
Lunar Libration Region L_4	X				DAC 16	18,.95	32.6°	23.4°	39.2°	2485	26-1	5	X	X		X	X	X		
		X			NK 35	55,1.2	35.5°	24.0°	42.9°	2485	101-1	4			X			X		
Gum Nebula																				
Red Filter (610-700nm)			X		NK 35	55,1.2	35.5°	24.0°	42.9°	2485	107-2	4	X		X			X		
Blue Filter (420-510nm)			X		NK 35	55,1.2	35.5°	24.0°	42.9°	2485	107-2	5	X		X			X		
Earth's Darkside	X				DAC 16	Sxt, 8	2.0°	2.0°	2.0°	2485	26-1	9						X		
Special Opportunities																				
Lunar Eclipse		X			NK 35	55,1.2	35.5°	24.0°	42.9°	2485	101-1	15	X		X			X		
		X			HEC 70	80,2.8	36.7°	36.7°	51.8°	SO-368	17-31	12						X		
		X			HEC 70	250,5.6	36.7°	36.7°	51.8°	SO-368	17-31	8						X		
SIVB	X				DAC 16	Sxt, 8	2.0°	2.0°	2.0°	2485	26-1	7						X		
Gegenschein/Moulton Region	X				DAC 16	18,.95	32.6°	23.4°	39.2°	2485	26-1	16	X	X		X	X		X	
			X		NK 35	55,1.2	35.5°	24.0°	42.9°	2485	107-2	11	X			X			X	
Solar Corona																				
Sunrise (East of Sun)		X			HEC 70	80,2.8	36.7°	36.7°	51.8°	2485	33-1	15	X							X
			X		HEC 70	80,2.8	36.7°	36.7°	51.8°	2485	107-2	14	X							X
				X	HEC 70	80,2.8	36.7°	36.7°	51.8°	2485	108-1	7	X							X
Sunset (West of Sun)		X			HEC 70	80,2.8	36.7°	36.7°	51.8°	2485	33-1	8	X							X

Table 3

reached the take-up spool.

Accessories and supporting equipment for this camera included a bracket (Br) which could be manually attached to a fixture on the right-hand rendezvous window frame. The other end of this bracket was a slide shoe and lock which could accept a grooved rail on the side of the camera body. When so mounted, the camera's optical axis had to be turned by a right-angle mirror (RM) attached on the outer end of the lens housing. In this mechanical arrangement the camera was out of the CMP's way, but it could view a region centered in the direction of the +x axis. The camera received its 28-volt, direct current operating supply through a special power cable (PC) that was manually connected to the camera and to a nearby spacecraft power receptacle to provide automatic film advance and shutter mechanism drive. A second plug on the camera body accepted a remote control cable (RC) for control of shutter speed and shutter actuation. The DAC could also be used with the Command Module (CM) sextant. In this mode of operation an adapter sleeve replaced the lens with one end of the sleeve used in place of the sextant eyepiece. This configuration provided a 2° circular field of view on the celestial sphere with an acceptance cone f-number of 8; however, beam splitters in the sextant's optical train decreased brightness by an additional factor of 4 for an effective speed of f/32.

35mm Nikon Camera

The 35mm Nikon camera, manually actuated, with 55mm, f/1.2 visible light transmitting lens was the main item of equipment used to collect data on Apollos 15 through 17, inclusive. The slight reduction in speed was more than compensated by the reduced grain scale and larger field-of-view. The film was wound on spools in cassettes, each of which was stored in its own separate container when not installed in the camera. The CMP was required to unstow and install each cassette, thread the film, rewind the used film back onto the cassette spool, remove and restow the cassettes by hand. Each cassette had about 48 usable data frames for the type 2485 film; however, the last eight frames at the end of the film strip were sometimes reserved for pre- and post-flight calibration step-wedge exposures by JSC's Photographic Technology Division (PTD) in addition to any other photometric calibrations applied by the APST Astronomy Working Group members.

Accessory equipments used with this camera included a mounting bracket which utilized the DAC bracket plus a second arm section added onto the bracket's slide shoe. The outer end of this second section had a captive screw with knurled knob to secure the camera body against the arm. The captive screw rode in a slot so that the camera's field-of-view could be aligned parallel to the CM +x axis or 30° up from that axis towards the -z axis. This second position was exactly normal to the glass of the right-hand rendezvous window, and it also permitted sufficient clearance from the inner pane for use of the front-end, plane-polarized, rotating filter assembly. Metal holders for the color filters were designed small enough so that they could be used with the camera in either alignment. Two different color filters were used in these studies--a red filter using Corning No. 2412 pyrex glass, 2 millimeters thick, which passed wavelengths longer than 610 nanometers (nm), and a blue filter using Corning No. 5030 pyrex glass, 2 millimeters thick, which passed wavelengths shorter than 510 nm. However, the window panes were coated to reject ultra-

violet light for crew protection and the type 2485 emulsion could not record light in the deep red. As a result the effective photographic bandpasses were 420 to 510 in the blue and 610-700 in the red.

70mm Hasselblad Camera

The 70mm Hasselblad electric camera with 80mm, f/2.8 lens was battery-powered, providing automatic film advance and shutter mechanism drive. For solar corona and zodiacal light work it was mounted behind the right-hand rendezvous window on its own bracket that was attached to spacecraft interior structure near the window. For the lunar eclipse color photography on Apollo 15 using Eastman Kodak, SO-368 color exterior emulsion, the Commander (CDR) hand-pointed the camera's line-of-sight through the left-hand rendezvous window, and he also changed to the 250mm, f/5.6 lens for portions of this sequence. This camera was used as the primary data-collecting equipment for solar corona experiments S-210/212 because the light levels were bright enough to use the slower lens f-number and also because it provided the largest field-of-view on the celestial sphere. When loaded with type 2485 film, the Hasselblad film magazines held about 115 frames; however, some film was available beyond the last frame, and this was reserved for PTD calibrations use in addition to any of the frames at the front of the film strip devoted to APST calibrations.

Window Shield

The only other item of equipment employed in these studies was a window shield (Sh) specially designed to meet Experiment S-178 requirements. This shield was a flat, black plate conforming to the shape of the right-hand rendezvous window. To avoid light leaks found in mock-up tests, a curve of black fabric was added to the top edge and outer corner of the plate to go over the window frame. An opening near the center of the plate was aligned with the 55mm lens of the Nikon camera when mounted on its bracket to view parallel to the CM +x-axis. Heavy black fabric was attached to the cabin side of the plate around this opening. With window shield and camera installed this tubular-shaped fabric could be pulled over the lens body and closed down snugly around it using draw strings. In this configuration, the camera optics and multiple panes of glass in the window could receive no light from the cabin to illuminate particulates or smudges on any of the glass surfaces. At the same time it permitted the CMP to use cabin lights for his operational needs to control the spacecraft and camera during the photographic sequences. At times when the window shield could not be used, such as with Hasselblad or for polarized light measurements, the CMP had to work in a dark cabin with only the readout display on the digital clock to time the sequence and duration of exposures. Between exposures, he used a small flashlight when changing camera or spacecraft equipment settings.

EXPERIMENTAL PROCEDURES

Just as accessory equipments were designed to minimize the chances for inadvertent exposure to extraneous, non-astronomical sources of light, so also were the specifications in experimental procedures and operational techniques. The avoidance of artificial illumination is quite difficult from manned spacecraft. From earth orbit further problems are encountered from natural sources, such as direct moonlight, its reflection from external parts

of the vehicle and from the earth's cloud cover, or illumination by the earth's airglow horizon -- all of which was amply demonstrated, unfortunately, in results from similar Skylab experiments. In fact, bright planets, stars or star groups too close to the phenomenon under study can cause final results to be suspect when viewed through a three-pane window where off-axis sources are not excluded by a light baffle passing just the camera's field-of-view.

Utilization of the double umbra while the CM was only sixty nautical miles above the absolute darkness of the lunar surface totally blotting out one-third of the sky provides ideal initial conditions, but special care had to be taken to suppress external flashes of light from thruster plumes. And yet, the use of thrusters was vital to the pointing of the camera's view and to the stabilization of spacecraft attitude so that image smear would be minimized over the long exposure times required. Several attitude control techniques were devised to deal with this problem. If no light source could be tolerated, the technique consisted of first changing spacecraft attitude so that the line-of-sight of the rigidly mounted camera was pointed at the astronomical subject with the image boundary properly oriented. The CMP accomplished this by inserting ground-computed position vector coordinates for vehicle axes into the on-board computer and these, in turn, were used by the guidance system to direct the firing of attitude thrusters. Then, three to five minutes of rate damping was performed to let the vehicle settle down to minimum values in attitude error excursions on the order of hundredths of a degree per second in each axis. Just prior to the first exposure the forward firing thrusters were deactivated. The number and duration of exposures depended on the phenomenon, camera equipment used, and length of time spent in the double umbra. The latter varied from as short as eight minutes early in the lunar orbital phase of the mission to over twenty minutes prior to spacecraft injection into transearth coast. To hold down nearby optical contaminants, dumps and fuel cell purges were not scheduled for at least one orbit or often longer prior to the photography. The attitude and rate damping control had to be started several minutes prior to entry into double umbra to optimize observing time, so that total operational time took twenty minutes at the least and an hour at most for each use of a double umbra pass.

In the case of zodiacal light photography, the phenomenon had to be covered by many adjacent, overlapping exposures for two reasons. First, its photographable portion covered a considerable length along the ecliptic, approximately the entire ninety degrees elongation from the sun. Second, the light levels were varying over brightnesses ranging from about 10^{-13} to 10^{-8} of the sun's surface brightness; so, it was necessary to change exposure times to achieve a useful emulsion density for photometric analysis Adjacent regions were actually photographed in a series of sequences. Each sequence was composed of two or three photographs differing from each other in exposure times by a factor of two to four times. This spread of exposures assured that the phenomenon would be properly exposed in at least one frame, and any frames showing overexposure along the ecliptic at the end nearest the sun would still provide good density off the ecliptic axis and at the far sun end. At large elongation angles the initial long duration exposure of the sequence only permitted time for one other short exposure. At mid elongations the sequences had three exposures usually differing by a factor of three. Close in to the sun the light levels changed so rapidly that individual frames were taken at almost regular intervals up to less than one degree of the sun. Ideally it would have been

best to fix the camera's line-of-sight on each selected target point along the ecliptic, but operationally this was not possible. Any change in spacecraft attitude from one fixed position to another takes several minutes, and damping of rates is just not satisfactory if the procedure is rushed. Therefore, for zodiacal light photography the decision was made to allow the spacecraft's attitude to change smoothly at lunar orbital rate of three degrees per minute in order to hold the portion of lunar limb occulting the ecliptic just in the edge of the camera's field-of-view. While this caused image smear proportional to exposure time, it permitted the CMP to concentrate on the tedious and complicated set of camera manipulations with a minimum of distraction in monitoring attitudes and rates.

OPERATIONAL ACCOMPLISHMENTS

Table 4 is a brief history of accomplishments by flights. It also includes work performed at Dunkelman's request on Apollo 8 and work planned for Apollo 13, the aborted lunar flight. While the efforts expended on these two missions were smaller in scope than on subsequent missions, they were very important to later results because they developed well-integrated working relationships and initiated the assignment of supporting responsibilities between the astronomical members of the APST and the many groups within NASA and among its contractors. Figures 2 through 5 show examples of specific results and explanations of conditions associated with the photography.

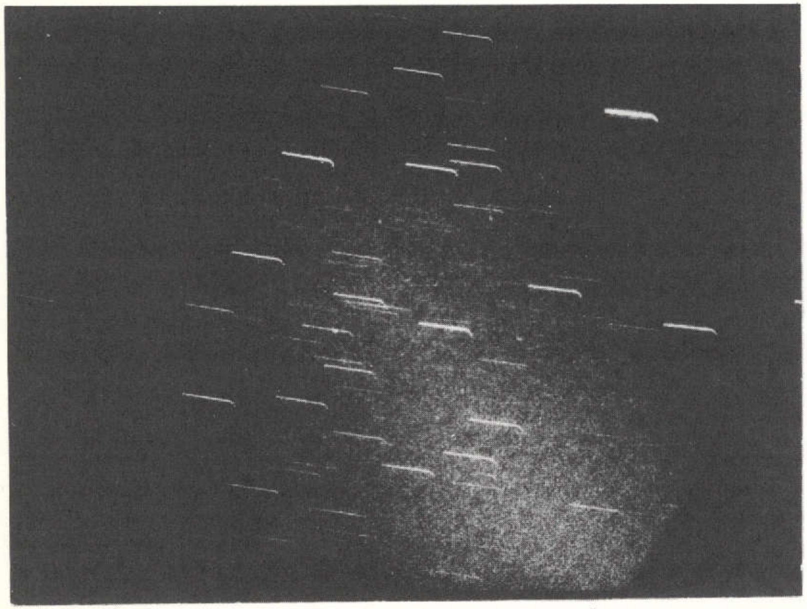
Preliminary scientific results have been reported previously by NASA (Mercer, et al., 1971; Dunkelman et al., 1972a; Mercer et al., 1972; Mercer et al., 1973a) and at the fifteenth plenary meeting of the Committee on Space Research (COSPAR) in Madrid (Mercer et al., 1973b). These reports include the preliminary results of solar corona studies under Experiment S-212. Experiment S-178 proved successful on Apollo 16, its second attempt to collect data (Dunkelman et al., 1972b). The reported successes are attributable to the lessons learned from prior work by Low Light Level Working Group members and their NASA operational counterparts in all of those related tasks, as well as to the efforts of flight crewmen performing the photography. Tasks that were not accomplished as planned or not attempted usually fell victim to real-time changes in flight planning to deal with operational problems or to accommodate higher priority experimental work. However, operation of the DAC with high-speed film using the sextant failed either because internal edge-lighting of scribed reticles overexposed the field-of-view at all exposure durations, even though this lighting was set on minimum intensity, or because earth's darkside photography could not avoid off-axis glare from the lighted portion of the earth. The galactic cluster photography on Apollo 16 using exposures of five minutes duration did not succeed because of excessive image smear, but this was hardly surprising. It was considered remarkable by APST members that the four-minute exposure of the L_4 region on Apollo 15 recorded just under one degree of smear. This indicated that the stability characteristics of the CSM could handle exposures of four minutes but not much more. In a sense, the demonstration of this limit did satisfy investigators that camera and emulsion speed versus stability had been pushed right to the limit, and the full potential of low light level photography from the double umbra had been realized under the circumstances.

APOLLO LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY: HISTORY OF DATA ACQUISITION

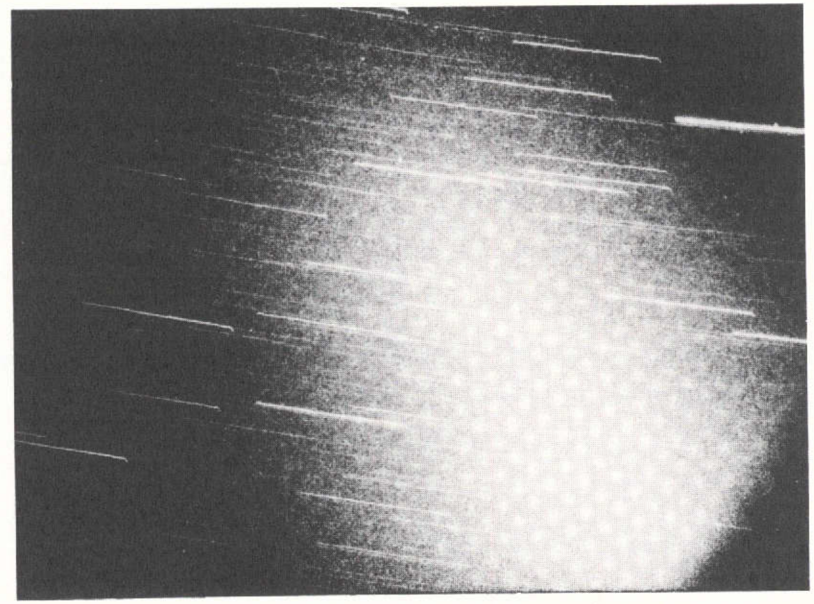
Flight No.	Task Additions and Changes	Phenomena Observed	Results
8	Several emulsion types carried for radiation effects studies.	Calibrated film strips.	Radiation fogging levels acceptable.
13	16mm DAC magazines with type 2485 film. Window shield developed to block cabin lighting from camera optics	Comet Bennett	Attempted but unsuccessful
		Solar corona east of sun	Not attempted
		Zodiacal light	Not attempted
14	Exposure times no longer than 20 sec. to minimize image smear from undamped vehicle rates	Zodiacal light east of sun on ecliptic	Partially successful
		Lunar libration region L_4	Not successful
		Interstellar light survey of Milky Way	Partially successful
		Earth's darkside using sextant	Not successful
		S-IVB photos using sextant	Not successful
15	35mm Nikon camera with 55mm, f/1.2 lens added to improve resolution versus 2485 grain size for S-178 Exposure times increased up to four minutes	Solar corona both east and west of sun	Both successful
		Zodiacal light eastward	Successful
		Lunar libration region L_4	Successful
		Lunar eclipse in color and in 2485 emulsions	Successful in color, partially successful in 2485
		Sextant photography usefulness	Not useful
16	Polaroid, red and blue filters for Nikon camera Exposure times increased up to five minutes	Solar corona east and west of sun	Successful eastward only
		Gum nebula	Partially successful
		Zodiacal light in polarized light	Not successful
		Galactic clusters in Virgo and Centaurus	Not successful, image smear limitations exceeded
		North celestial pole	Not attempted
17	Crew sketches of visual observations requested	Solar corona east and west of sun and sketches of visual scene	Successful photography eastward only, crew sketches successful
		Zodiacal light in red, blue and polarized light	Successful in all three bandpasses

Table 4

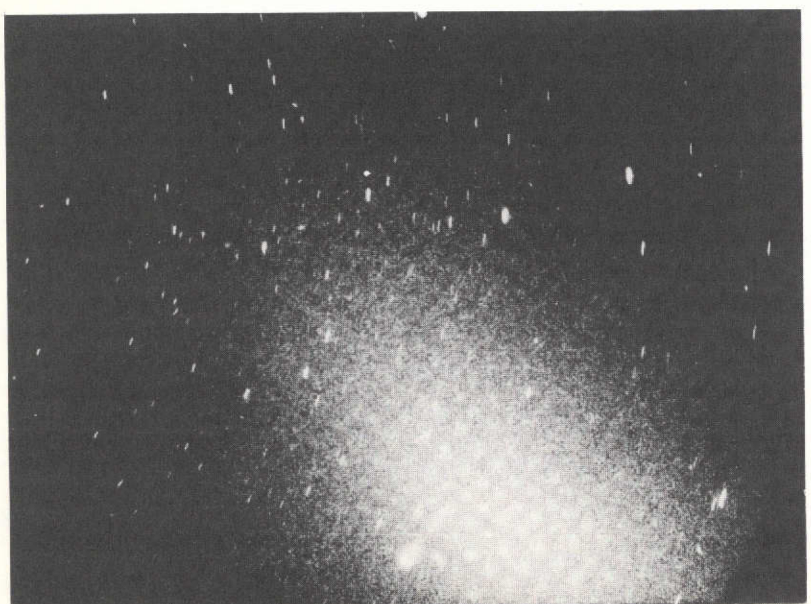
Apollo 15 Zodiacal Light Photography with Nikon 35 mm camera, 55 fl lens at f/1.2 on Kodak 2485 film.



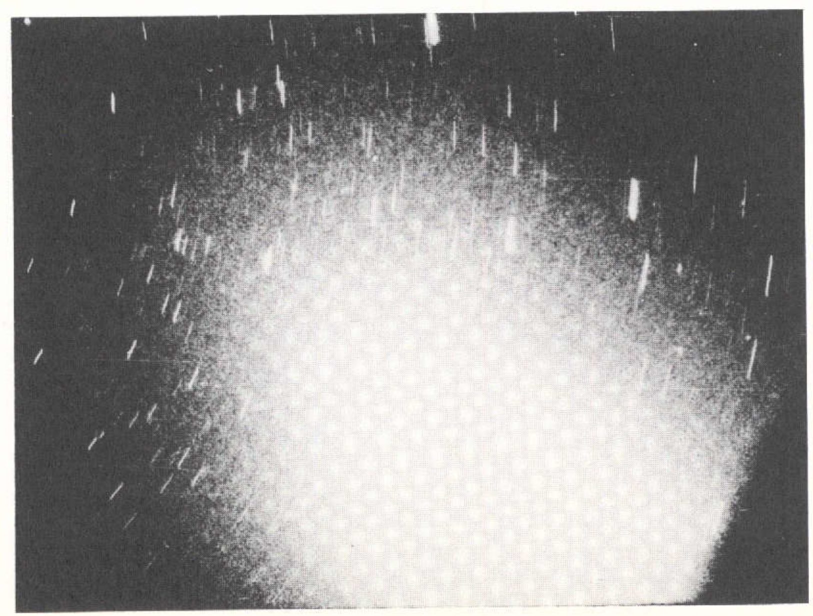
20 sec exposure along ecliptic 45° from sun; dark lunar limb in lower right 25° from sun.



60 sec exposure along ecliptic 45° from sun; dark lunar limb in lower right 25° from sun.



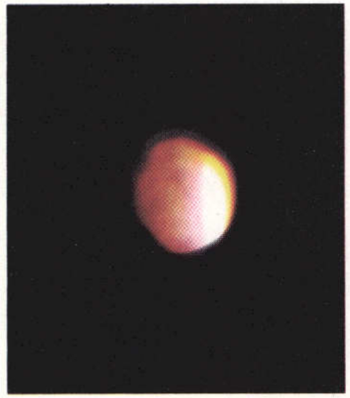
10 sec exposure along ecliptic 35° from sun; dark lunar limb in lower right 15° from sun.

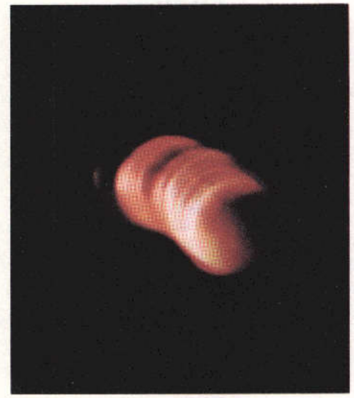


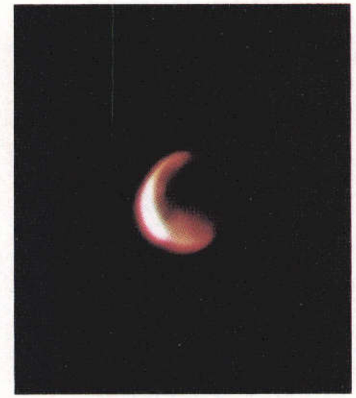
30 sec exposure along ecliptic 35° from sun; dark lunar limb in lower right 15° from sun.

Figure 2

STUDY FROM APOLLO 15 OF EARTH-ATMOSPHERIC, EDGE-ON TRANSMISSION CHARACTERISTICS OF SUNLIGHT USING A LUNAR ECLIPSE



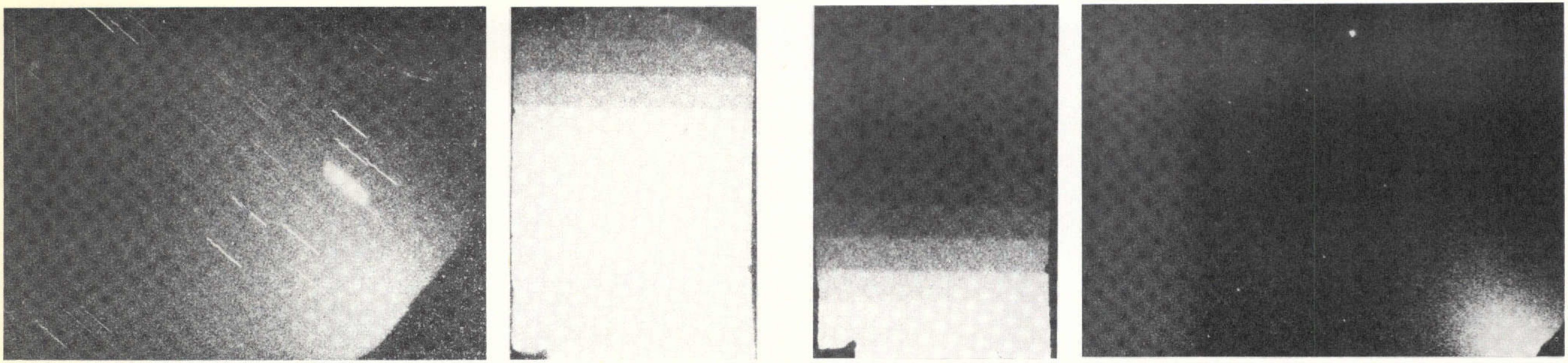




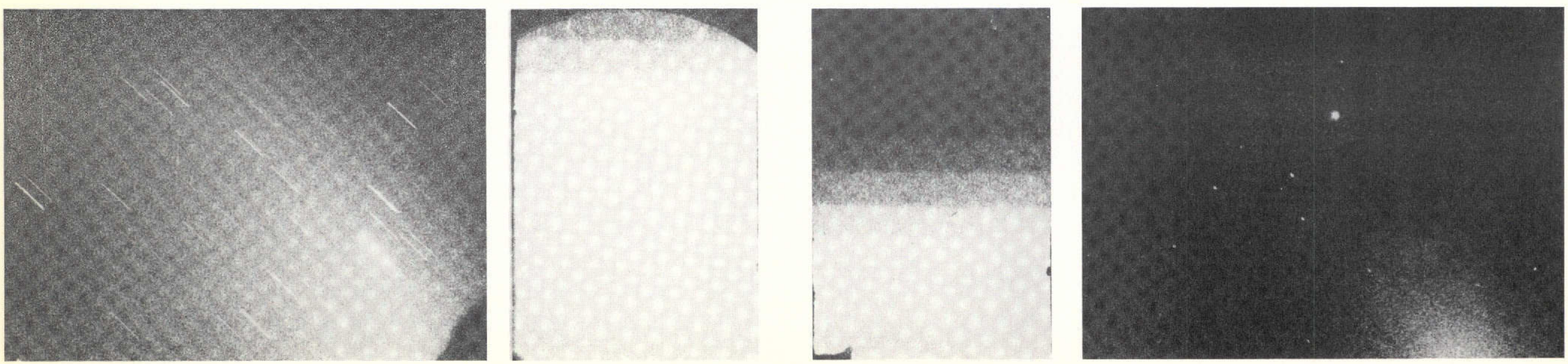
The lunar eclipse of August 6, 1971, which occurred while the Apollo 15 spacecraft was returning from the moon, was recorded in two series of photographs. The purpose of this photography was to record the relative differences in the color of light passing through the earth's atmosphere as a function of altitude with the moon serving as a projection screen. It also provides a composition and sharpness of color reference for comparison to future observations of moons being eclipsed by planets with different atmospheres. The first series consisted of eleven exposures taken over a sixteen-minute period before and during the moon's entry into the earth's shadow. A second series of ten photographs were obtained over a like period of time as the moon was leaving the shadow. Even when the moon was not in total eclipse during these series, it was undergoing partial eclipse in the penumbral region. All of these photographs were taken by Astronaut David R. Scott hand-holding the 70mm format electric Hasselblad camera at the left-hand rendezvous window of the Command Module. The first four frames of the eclipse entry series and the last four frames of the eclipse exit series were made with the 250mm, f/5.6 lens working at maximum aperture. At the lower light levels, where long time exposures were required, the 80mm, f/2.8 lens was used at maximum aperture. All photographs were recorded on the same film strip of Eastman Kodak SO-368, an emulsion used for color exterior scenes. The larger view on the far left (NASA Photo AS15-96-13108) is a two-second exposure taken twelve minutes prior to the moon's entry into total eclipse and the only exposure presented here using the 250mm lens. The smaller view on the left (NASA Photo AS15-96-13113) is another two-second exposure taken six minutes prior to eclipse entry. Just right of center is a two-minute exposure (NASA Photo AS15-96-13118) showing multiple images and begun one minute before the moon came out of eclipse. At far right is another two-second exposure (NASA Photo AS15-96-13120) taken six minutes after exit from the eclipse. In each of these scenes the white light, wherever it appears, is penumbral lighting of the lunar surface. The orange-to-red-to-brown band is light transmitted through the earth's atmosphere with more and more of the shorter wavelengths -- first blues, then blues and greens -- diffracted and dispersed by Rayleigh scattering. No effect of blue wavelengths refracted towards the center of the umbra is present, although the path density of atmosphere penetrated increases by many orders of magnitude from orange twards the brown edge of the color band.

Figure 3

Apollo 17 Zodiacal Light, Dec. 12, 1972 -- Nikon 35 mm camera, 55 mm lens at f/1.2, color filters, Kodak 24[illegible] film

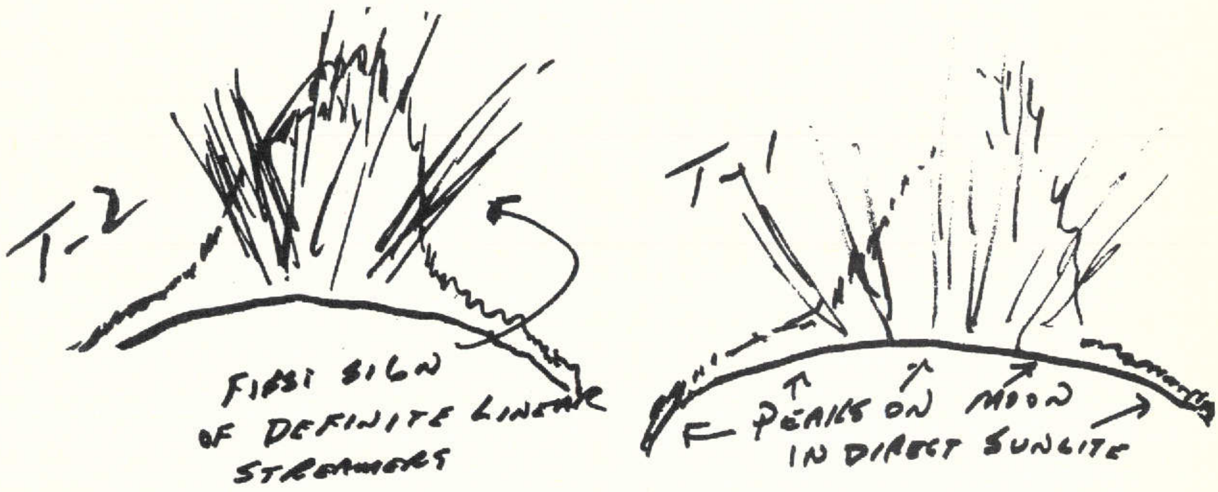


Red (∼620-700 nm) zodiacal light scenes located eastward on ecliptic with corresponding calibration wedges. 40 sec. exposure on left is centered at 35^{o} elongation, with sun 15^{o} below lunar limb at lower right corner; 2 sec. exposure on right centered at 25^{o} elongation with sun 3.5^{o} below lunar limb (AS17-159-23908 & 23912).

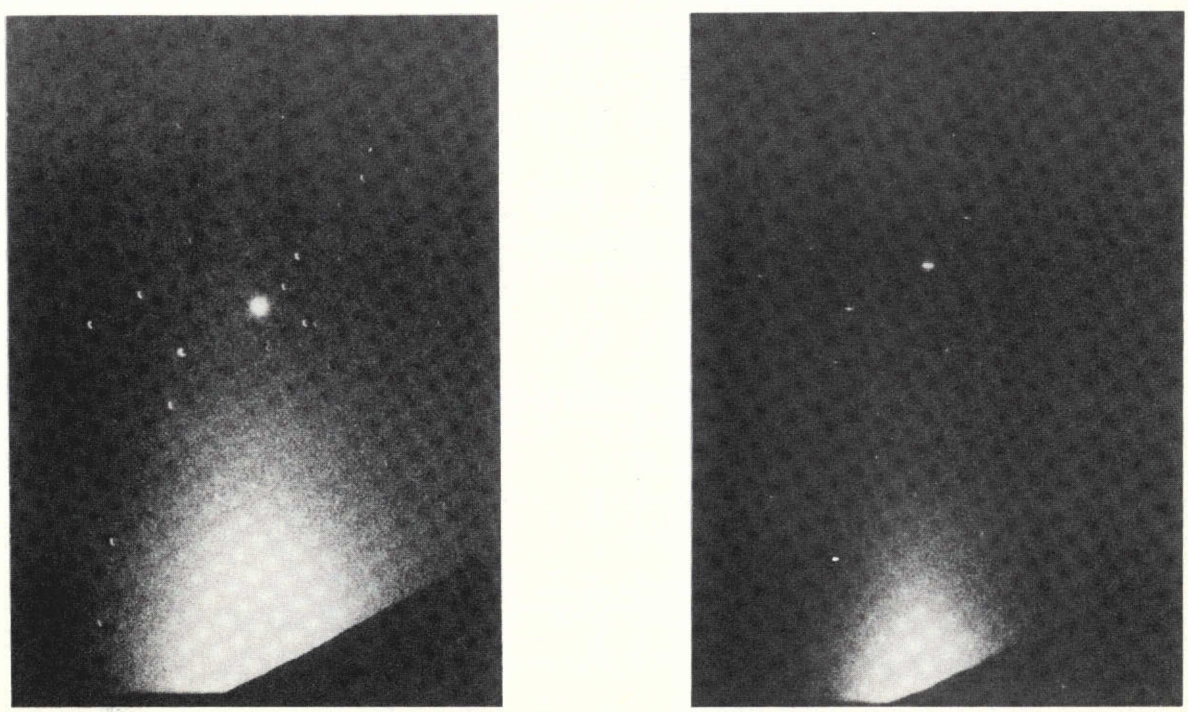


Blue (∼420-510 nm) zodiacal light scenes located eastward on ecliptic with corresponding calibration wedges. 40 sec. exposure on left is centered at 35^{o} elongation, with sun 15^{o} below lunar limb at lower right corner; 2 sec. exposure on right centered at 25^{o} elongation with sun 3.5^{o} below lunar limb (AS17-159-23937 & 23941).

Figure 4



Solar corona and zodiacal light sketched by Commander Cernan as it appeared visually from lunar orbit two minutes and again at one minute prior to sunrise.



Photographs of outer corona and inner zodiacal light in plane-polarized, white light using the 35mm Nikon camera, 55mm lens set at f/1.2 and Kodak 2485 high-speed recording film. Exposures of 5-seconds on left and 1-second on right were taken at two minutes and at seventy seconds prior to sunrise.

Figure 5

PHOTOGRAPHIC CALIBRATION

All type 2485 flight film underwent standard calibration by PTD. This sensitometry employed a twenty-two step density strip contact printed for 1/100th of a second on the flight film using illuminant B at 2850°F with color-correcting and intensity-limiting filters making the illumination equivalent to a 5500°K source with SCW and 1.0 ND filters. Each step of the wedge differed by a log exposure value of 0.15 and the dimmest step had an absolute exposure value of about 6×10^{-10} meter-candle-seconds. Control strips of the flight film were identically calibrated by PTD and used to establish postflight photoprocessing equivalence to the desired, preflight density versus log exposure curves before committing the flight film to development. These procedures, controlled by PTD and carried out by their on-site contractors, preserved the quality of all low brightness, astronomical photography on Apollo. Data was neither lost nor degraded in photoprocessing as a direct result of the diligent efforts and concern exhibited by these groups. Extensively detailed information on calibration and photoprocessing control are contained in internal documentation and numerous records at PTD.

On Apollo 14 both preflight and postflight calibrations were added by the APST Low Light Level Astronomy Working Group. These consisted of sets of sixty-, twenty- and five-second exposures to a nine-step grey scale reflectance chart. It was illuminated by a nine lambert, diffuse source perpendicular to and two meters from the chart. Calibration exposures were made two meters from this chart and 20° from its normal so as to avoid the path of the illuminating source.

On Apollos 15 through 17, inclusive, transportable Sensitometer Boxes, designed by HAO for calibration of film on Skylab Experiment S-052, White Light Coronagraph, were used to calibrate all low brightness, astronomical photography emulsions (Pizzo and Gosling, 1972). These Sensitometer Boxes provided a solar-referenced, color-corrected, diffuse illumination of a neutral density step wedge at f/13.7 (see Figure 4). Test film strips exposed to these calibration wedges were also exposed to sunlight illuminated, diffusing opals and neutral density filter combinations under very clear skies at high altitude. Photographic density correspondence on these test strips was used to establish the values given below where $B_{\odot}$ refers to the sun's average surface brightness.

Step	Apollo 15 Calibration $B/B_{\odot}$ (Sensitometer Box #1)	Apollos 16 and 17 Calibrations $B/B_{\odot}$ (Sensitometer Box #2)
1	-	1.02×10^{-9}
2	1.03×10^{-8}	7.25×10^{-9}
3	6.38×10^{-9}	4.90×10^{-9}
4	4.18×10^{-9}	3.24×10^{-9}
5	2.71×10^{-9}	2.24×10^{-9}
6	1.76×10^{-9}	1.41×10^{-9}
7	1.12×10^{-9}	9.12×10^{-10}
8	7.65×10^{-10}	5.89×10^{-10}
9	5.05×10^{-10}	4.27×10^{-10}
10	3.59×10^{-10}	2.77×10^{-10}
11	2.47×10^{-10}	1.86×10^{-10}

Step	Apollo 15 Calibration $B/B_\odot$ (Sensitometer Box #1)	Apollos 16 and 17 Calibrations $B/B_\odot$ (Sensitometer Box #2)
12	1.72×10^{-10}	1.23×10^{-10}
13	1.23×10^{-10}	8.65×10^{-11}
14	8.52×10^{-11}	6.16×10^{-11}
15	6.50×10^{-11}	4.78×10^{-11}

While the sensitometry by PTD and HAO appears quite similar in general, the use of exposure times is the important difference between them. PTD uses a standard 1/100th of a second. Exposures used with the HAO Sensitometer Boxes exactly duplicated the exposures to be used in flight. For long exposures neutral density filters were placed between the diffuse source and the step wedge to achieve the desired density levels on the film; otherwise, they would have been overexposed. The matching of exposure times between data and calibration frames was vital in eliminating reciprocity failure characteristics. Reciprocity failure refers to the fact that a photographic emulsion, as a detector that integrates photons over time, fails to respond the same to an equal number of photons if the period of time over which they arrive is not equal. Thus, a two-minute exposure to a given intensity will have less density than a one-minute exposure to twice the given intensity. The reciprocity relationship fails to hold. Because of the low brightness nature of the subject matter and the long exposures required it was impossible to avoid severe reciprocity effects in the data. However, by matching durations of data and calibration exposures, both of which had the same history of temperature, pressure, particle/x-ray radiation and photoprocessing, the known light levels of densities in the calibration frames can be directly related to densities in corresponding data frames. Furthermore, the color and polaroid filters used in flight were also used in the Sensitometer Boxes to establish transmission losses in terms of absolute brightnesses.

SUPPORTING TESTS

Supporting tests include not only solar calibration of the HAO Sensitometer Boxes already described, but also they include emulsion sensitivity, radiation fogging and processing tests by PTD, real-time ground support data-collection tests and lens vignetting tests. The emulsion sensitivity to radiation was studied by PTD as a part of their internal Skylab Program support efforts (Lamar, 1967). However, the results were of value for type 2485 emulsion even though Apollo lunar flights experienced a dose of about one rad or so, much less than was expected for the Skylab flights. The type 2485 emulsion had evolved at Eastman Kodak from earlier emulsions, such as types 2475 which had been used on Gemini flights by Dunkelman and Mercer, and 2484 which was almost as fast as 2485 but was purported to be less sensitive to radiation fogging. Part of these comparisons depended on photoprocessing techniques which had to be properly devised anyhow. Thus, PTD had one of their contractors study these matters (Reed, 1970a and b), and this information was of direct importance to Experiment S-211.

During Apollo missions 15 and 16 low brightness, astronomical studies were performed from the ground using the flight backup film in the 35mm Nikon camera. This photography was made as similar as possible to the flight photography; however, because of site locations and their associated day/night lighting and weather conditions, it was not possible to perform flight and ground photography

in unison nor even to have available the same portion of the celestial sphere. For example, Mr. Dave Hultquist performed photography near the 10,000-foot level on Mt. Haleakala, Maui, Hawaii during Apollo 15 in coordination with the Low Light Level Astronomy Working Group. But, he had to wait for the first quarter, waxing moon to set at local midnight before he could begin his photography. His data on the zodiacal light covers the morning or western elongations from the sun. The Apollo 15 CMP also obtained sunrise zodiacal light, but because of the orbital direction this data covered eastern elongations. Hultquist also photographed the L_4 region, the sextant stellar photography test region and, for Experiment S-178, the gegenschein/Moulton region. Dunkelman also performed some ground photography from McDonald Observatory in West Texas during this mission. These data have not been carried beyond photoprocessing pending the outcome of the flight data. On Apollo 16 weather at the Maui station made observations impossible, although Dunkelman got some data in West Texas where he was also contending with weather problems.

The major supporting test work involved the determination of lenses' vignetting functions. All flight lenses have been tested except the Apollo 14 lens for the DAC. That lens, which was used for training, was accidentally destroyed. A very similar lens is now awaiting testing whenever facilities and personnel at GSFC can continue this work. Vignetting refers to the fall off of brightness in an image from a camera operated at a very fast lens setting. It causes equal brightnesses further and further from the optical axis to appear dimmer and dimmer. This limitation in uniform brightness is purely a function of the lens and is most severe at largest apertures, but it was necessary to use such settings to obtain every photon available from each phenomenon. Fortunately, a photograph on film with photometric sensitometry of a constant-valued illuminated surface as seen by the same lens and settings can document this brightness fall-off with respect to every part of the scene. The inverse function to the fall-off can, thereby, be found and applied to flight data frames to restore their seemingly weak peripheries. These restored frames, if there is no smear, should show the full scene and phenomenon in their true brightness relationship. A detailed description of the vignetting test setup was given for analogous photography in Experiment S073 on the Skylab 4 mission (Mercer, 1974b). Figure 6 shows the test set-up and Figure 7 taken from the Skylab 4 report clearly documents the equipment and light source arrangement for performing these tests. Except for a square cannister from Skylab Experiment T025 utilized by Experiment S073, the set-up for S-211 tests was identical; however, documentary photographs could not be taken at that time.

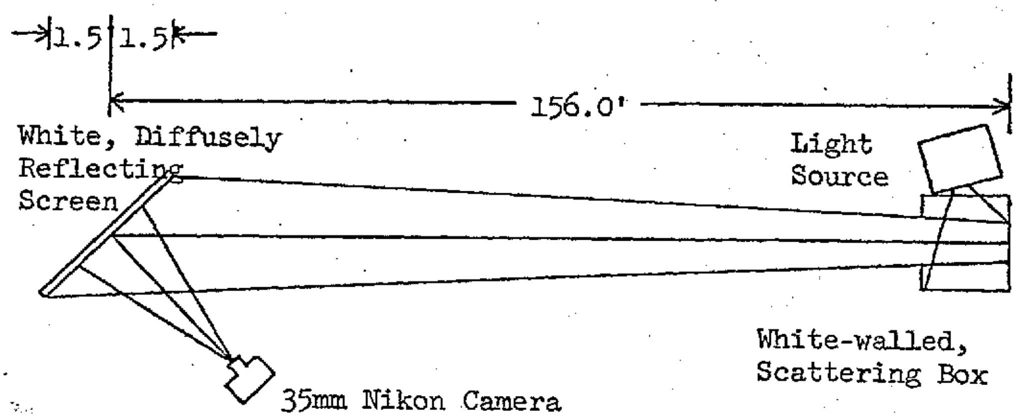
DATA PROCESSING AND ANALYSIS

Figure 8 is a block diagram of the entire data processing and analysis flow. The horizontal, solid black line two-thirds of the way down indicates the approximate status of this work at present. Data processing began after each mission with the postflight calibrations and photoprocessing of flight, flight calibrations, ground and ground calibrations data. The next step was the compilation of quick-look identification lists, a tedious but necessary task to bring all pertinent supporting data together for an assessment of quality and priorities in the processing. This included identification of the subject matter; the celestial or selenographic coordinates of each frame; the date, starting times and duration of each exposure; telemetered camera actuation times; log books; checklists; air-to-ground voice transcripts; on-board tape

LABORATORY SET-UP FOR LENS VIGNETTING TESTS

2.77 2.84	2.77 2.86	2.81 2.88	2.85 2.93	2.90 3.00
2.77 2.83	2.82 2.88	2.84 2.93	2.89 2.96	2.93 3.00
2.80 2.87	2.82 2.88	2.85 2.92	2.89 2.96	2.94 3.00
2.81 2.86	2.83 2.88	2.86 2.91	2.90 2.96	2.96 3.00
2.81 2.83	2.82 2.84	2.85 2.88	2.89 2.90	2.94 2.94

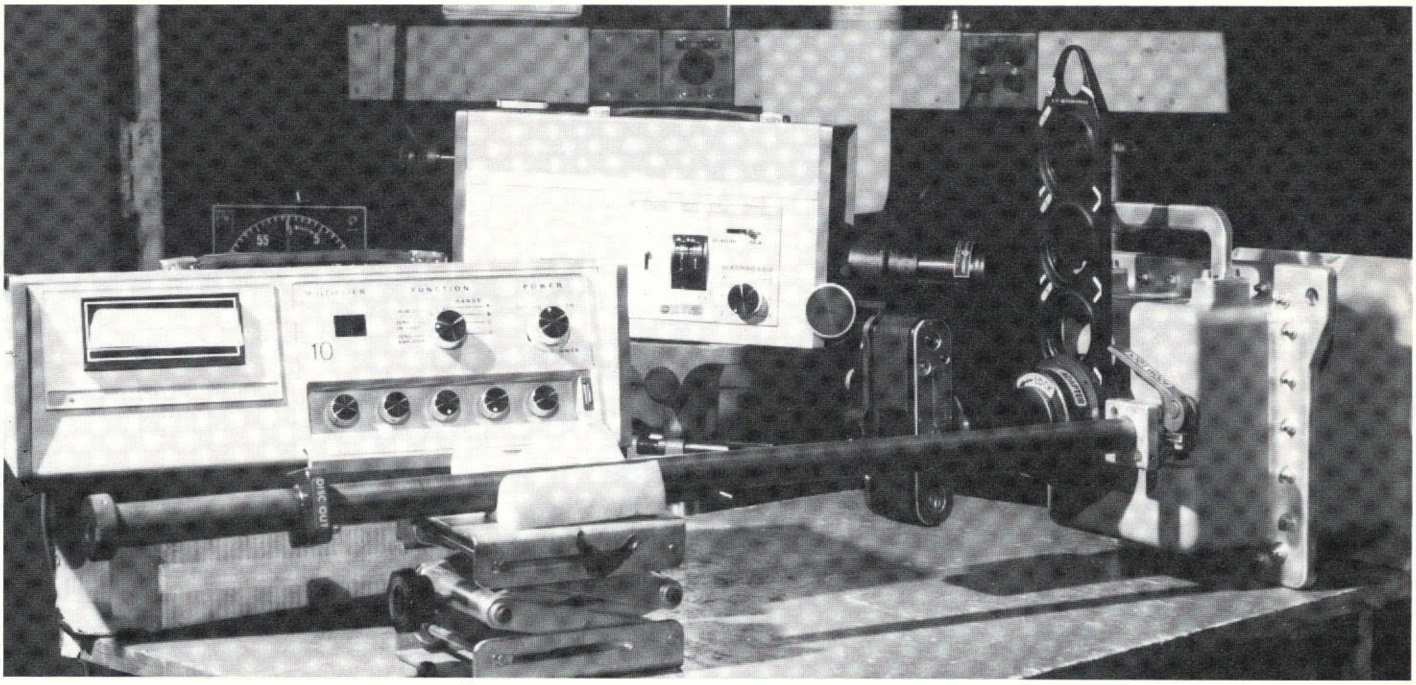
Front view diagram of vignetting test screen showing array of reflectance readings using Pritchard Photometer. All readings are in 10^{-4} foot-lamberts. Each sector was read once beginning at upper left, always moving left to right, progressing to next lower row and finishing at lower right; this procedure was repeated to produce second set of readings. Screen had very weak specular characteristics which produced brightening towards right side near center as angle of reflectance approached angle of incidence from source.



Top view diagram showing arrangement of illuminating source, diffusely reflecting screen and Apollo camera with lens in test position for the collection of vignetting data. Area of screen used provided white light field uniform to approximately ±2%.

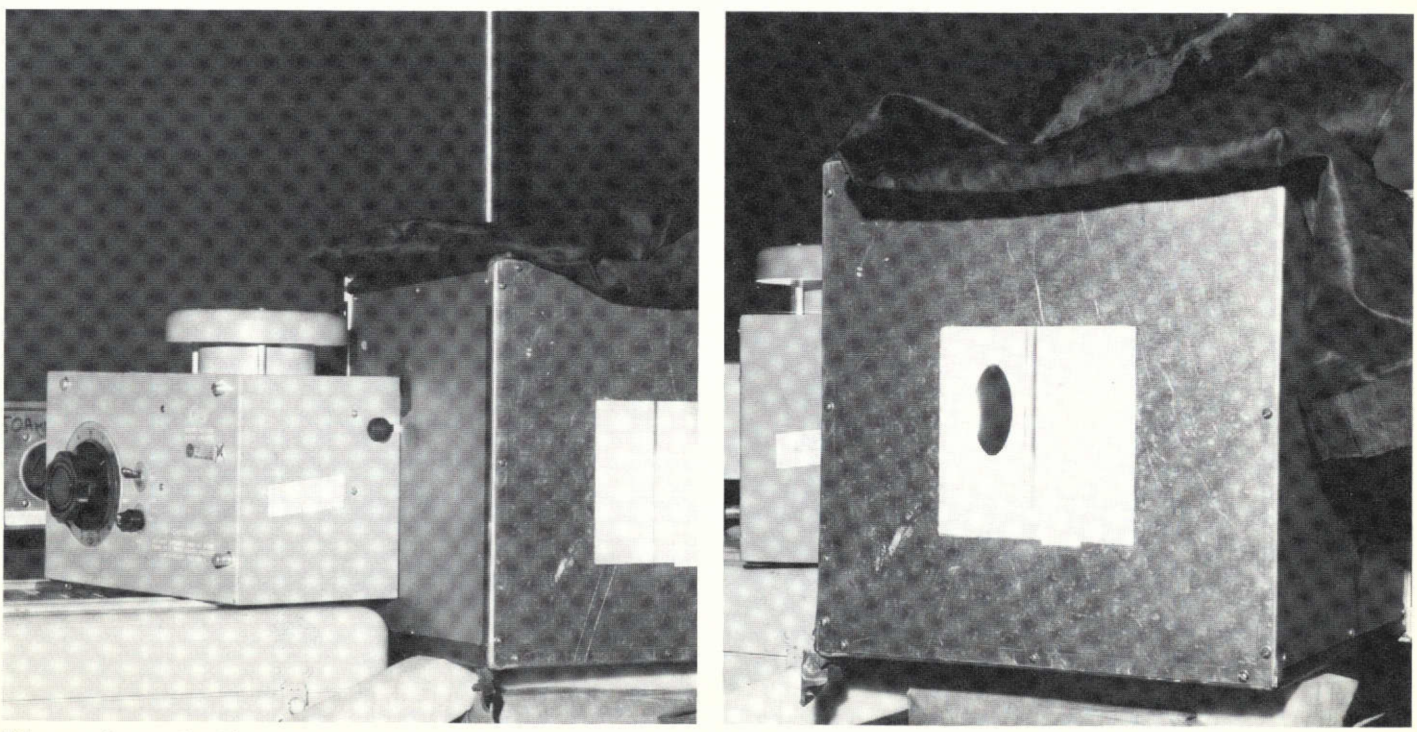
Figure 6

EXPERIMENT S073 VIGNETTING TEST ARRANGEMENT WITH T025 EQUIPMENT



Nikon 35mm Camera with UV, f/2.0 lens attached to quartz window port at rear of T025 cannister to obtain photographs for assessing system vignetting. Diffusely reflecting screen providing constant illumination over the test field is out of view to the right. Pritchard Photometer used to measure field illumination. (GSFC Photograph G-74-05542)

LIGHT SOURCE USED TO ILLUMINATE VIGNETTING TEST SCREEN



Views from left and right of light source for illuminating vignetting test screen a distance of 156 feet away. Light from Cary lamp illuminated white painted inner surface of metal box from side. Illumination source was diffuse reflection from back wall through aperture of about 3 inches square. (GSFC Photographs G-74-005543 and G-74-05541)

Figure 7

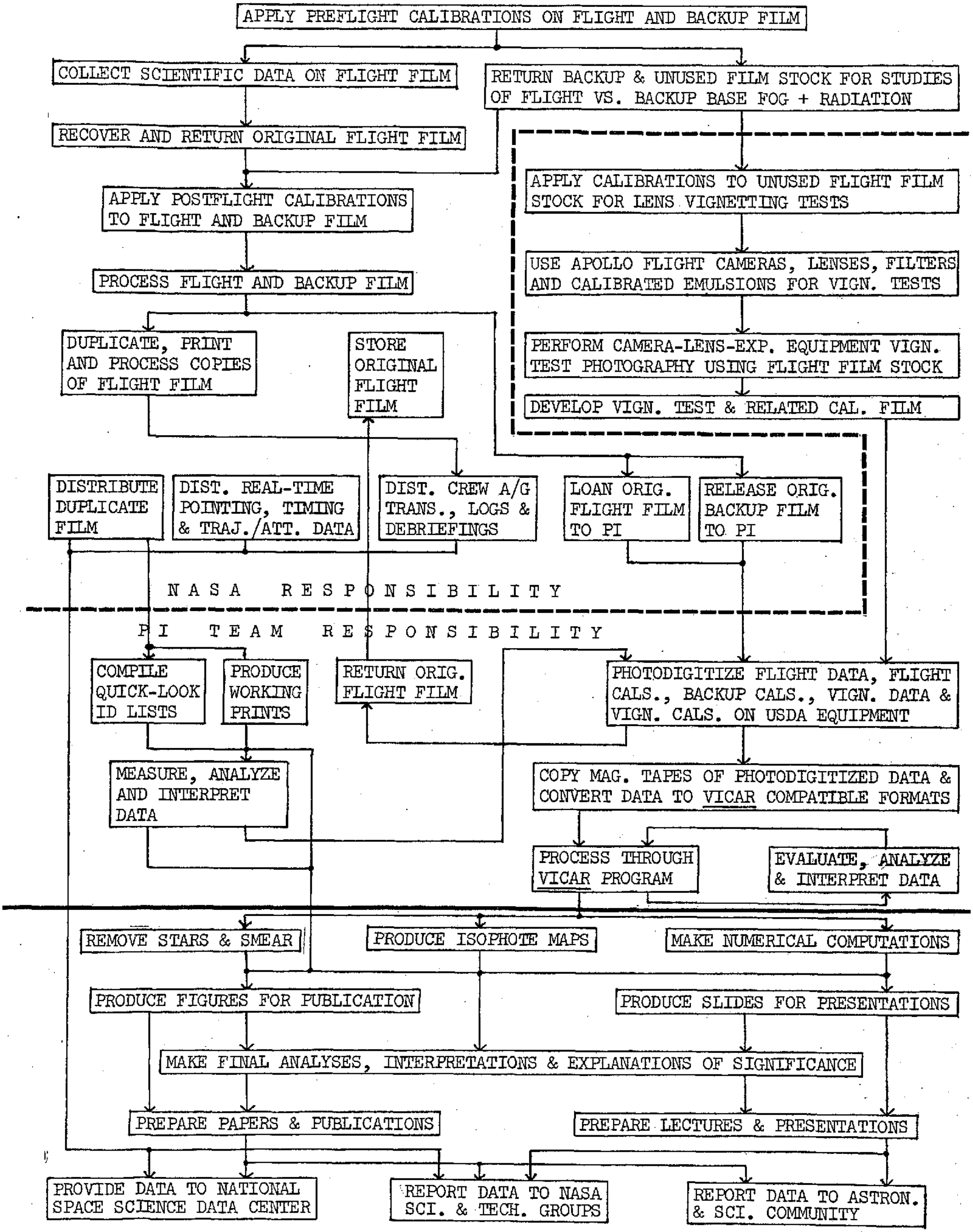

APPLY PREFLIGHT CALIBRATIONS ON FLIGHT AND BACKUP FILM
COLLECT SCIENTIFIC DATA ON FLIGHT FILM
RETURN BACKUP & UNUSED FILM STOCK FOR STUDIES OF FLIGHT VS. BACKUP BASE FOG + RADIATION
RECOVER AND RETURN ORIGINAL FLIGHT FILM
APPLY CALIBRATIONS TO UNUSED FLIGHT FILM STOCK FOR LENS VIGNETTING TESTS
APPLY POSTFLIGHT CALIBRATIONS TO FLIGHT AND BACKUP FILM
USE APOLLO FLIGHT CAMERAS, LENSES, FILTERS AND CALIBRATED EMULSIONS FOR VIGN. TESTS
PROCESS FLIGHT AND BACKUP FILM
DUPLICATE, PRINT AND PROCESS COPIES OF FLIGHT FILM
STORE ORIGINAL FLIGHT FILM
PERFORM CAMERA-LENS-EXP. EQUIPMENT VIGN. TEST PHOTOGRAPHY USING FLIGHT FILM STOCK
DEVELOP VIGN. TEST & RELATED CAL. FILM
DISTRIBUTE DUPLICATE FILM
DIST. REAL-TIME POINTING, TIMING & TRAJ./ATT. DATA
DIST. CREW A/G TRANS., LOGS & DEBRIEFINGS
LOAN ORIG. FLIGHT FILM TO PI
RELEASE ORIG. BACKUP FILM TO PI
N A S A R E S P O N S I B I L I T Y
P I T E A M R E S P O N S I B I L I T Y
COMPILE QUICK-LOOK ID LISTS
PRODUCE WORKING PRINTS
RETURN ORIG. FLIGHT FILM
PHOTODIGITIZE FLIGHT DATA, FLIGHT CALS., BACKUP CALS., VIGN. DATA & VIGN. CALS. ON USDA EQUIPMENT
MEASURE, ANALYZE AND INTERPRET DATA
COPY MAG. TAPES OF PHOTODIGITIZED DATA & CONVERT DATA TO VICAR COMPATIBLE FORMATS
PROCESS THROUGH VICAR PROGRAM
EVALUATE, ANALYZE & INTERPRET DATA
REMOVE STARS & SMEAR
PRODUCE ISOPHOTE MAPS
MAKE NUMERICAL COMPUTATIONS
PRODUCE FIGURES FOR PUBLICATION
PRODUCE SLIDES FOR PRESENTATIONS
MAKE FINAL ANALYSES, INTERPRETATIONS & EXPLANATIONS OF SIGNIFICANCE
PREPARE PAPERS & PUBLICATIONS
PREPARE LECTURES & PRESENTATIONS
PROVIDE DATA TO NATIONAL SPACE SCIENCE DATA CENTER
REPORT DATA TO NASA SCI. & TECH. GROUPS
REPORT DATA TO ASTRON. & SCI. COMMUNITY

Figure 8

recorder transcripts; crew debriefings and even trajectory and vehicle attitude data all play a part in building the quick-look identification lists. Examination of working copies of the film and production of working prints commenced early in the postflight period. A separate and parallel effort began as facilities and equipment became available to perform lens vignetting tests as previously described.

The originally proposed approach to image analysis required all useful data frames and associated photography be converted to digitized, photometric values using the Joyce-Loebl double-beam microdensitometer at GSFC. Stepped line scan readings of film density would be recorded on magnetic tape for later input to digital computers at GSFC. Density readings of calibrated step wedges contained on the flight film and of a second standard wedge for instrument calibration would also be recorded and used in a computer program to convert scene densitites to absolute brightness measurements. Finally, calibrated readings of each flight len's photometric transfer function, i.e. vignetting function, would be applied to brightness readings to arrive at light levels throughout the scene. A computer program to handle such inputs was in development by Wolff for Experiment S-178.

Digitization of Experiment S-178 data at GSFC proved to be much slower than originally anticipated, on the order of hours per full frame. Furthermore, the number of frames containing important astronomical data was running into the hundreds with half again as many flight calibration frames. The workload had grown well beyond what had been anticipated. Other means to carry out the necessary work had to be found. Also, the computer programs for S-178 were not sufficiently developed nor did they show the flexibility to handle even small digital arrays.

Photodigitization

Fortunately, several vendors were just beginning to produce more fully automated and faster photodigitizing equipments. Photodigitizing services were procured on a trial basis by GSFC, using their Intercenter Agreement funds, from both Photometric Data Systems (PDS) of Perkin-Elmer Corp. in South Pasadena and from Dicomed Corp. in Minneapolis. The results from PDS proved better for experimental requirements, and special arrangements were made with another PI, Dr. Don Von Steen, in the Earth Resources Technology Satellite (ERTS) Program at the Dept. of Agriculture in Washington, D.C. to use exactly the same equipment that had been utilized under the service contract at PDS. This saved considerable travel and service costs on the continuing photodigitization work.

The details of the photodigitization process are quite simple in principle. A square aperture, eighty microns on a side, of collimated, white light is allowed to pass perpendicularly through the original negative of a selected photographic frame. This beam then impinges upon a calibrated photomultiplier tube, and the developed grain in the photographic emulsion is put into focus at its photocathode. An output voltage of the photomultiplier is recorded in terms of density, i.e. in terms of the logarithm, base 10, of transmitted beam intensity. The beam is first stepped horizontally, eighty microns per step, completely across the frame in the "x-direction", which is parallel to a side of the square aperture. This is done by mechanically moving the stage, to which the film is attached, using computer controlled servomotors. At the end of this

line scan, the stage is stepped vertically downward in the "y-direction" by eighty microns and scanned back in the "negative x-direction". Individual readings and information on position are temporarily stored by the control computer, then written onto a magnetic tape as a string of values following the frame identification group loaded by the operator. One 35mm frame scanned side-to-side from the bottom part of upper sprocket holes to the top part of lower sprocket holes requires about eight minutes and produces 152,056 separate readings.

The grain size on the very high-speed, 2485 type emulsion is already on the order of ten microns; so, there is very little resolution loss using the eighty micron beam. The film could easily be digitized to a higher resolution, but that effort would prove wasteful in terms of the additional computer storage and data manipulations required. For instance, if the aperture were reduced to forty microns square, the photodigitization time, the data storage array size, and subsequent computer manipulations would each increase by four times. The vignetting frames are digitized just like data frames. Through computer processing of step wedge calibrations, emulsion density is converted to absolute intensity over the frame. The logarithm of these readings is normalized to zero at the brightest point on the optical axis near the center of the frame. At distances away from the optical axis, the log will have negative values of larger and larger magnitude. Earlier digitizations were performed at 36 microns and at 40 microns before computer results were available to indicate that there was little to be gained in terms of photometric accuracies. After this earlier photodigitization vignetting frames were digitized just like data frames. Step wedge images for calibrations of both the flight and the vignetting data were digitized across a sufficient width to produce a good sampling of value for each step in the wedge. This required a scan of one hundred lines.

Digital Computer Image Processing

Alternate computational techniques with sophisticated processors were eventually located to replace the S-178 data reduction software. One of these, at the Visibility Laboratory at La Jolla, involved a program running on an IBM computer totally dedicated to image processing work. However, those in charge of processing activities felt that the time required to support training and use on this system would overtax their limited staff and resources. Another system, the Video Image Communication and Retrieval (VICAR) Program, developed at the Jet Propulsion Laboratory (JPL) for processing televised data from Ranger, Surveyor, and Lunar Orbiter spacecraft, was satisfactory for S-211 requirements. Furthermore, it had already been acquired from JPL by Dr. Dan Klinglesmith at the Laboratory for his work on the International Ultraviolet Explorer (IUE) Satellite Program. Arrangements were made and advisory assistance was received from Klinglesmith so that S-211 could perform image processing with VICAR in return for manpower support by S-211 in the person of Mr. G.C. Alvord working at GSFC to help with additional VICAR processing of value both to S-211 and to other users as well. Also, funds under the Intercenter Agreement were used to acquire a Photowriter display device that has been especially useful for presenting results from VICAR output.

Table 5 gives an outline of the procedural steps necessary to reduce S-211 photodigitized images using VICAR. They are quite involved in detail, and it is very important to keep a log of computer runs, including cross-referenced

OUTLINE OF PROCEDURAL STEPS IN VICAR COMPUTER PROCESSING OF LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHS

A. Basic Image Processing

1. Compute histograms using VICAR processor Mask for each data, lens vignetting and calibration image, i.e., create a bar-chart graph showing the number of equal photometric readings at each specific value of density versus 256 possible density levels encoded in a VICAR image array (See Figure 9).

2. Clip base plus fog density from data frames using VICAR processor Diffpic, i.e., find the lowest-valued peak in the histogram, which represents the average value of density plus fog, and shift this density level value to zero by subtracting this value from all levels in the image array.

3. Print out histograms of step-wedge calibration images for data and vignetting photographs using VICAR processor List, and use this multi-peaked density distribution function to develop density versus absolute brightness curves, i.e. emulsion H&D curves.

4. Use VICAR processor Stretch with appropriate tables of H&D values to produce a digital array of logarithmic, absolute brightness values in data frame images and in corresponding lens vignetting images.

5. Determine registry between digital array versions of each data image and its corresponding lens vignetting image using VICAR processor Display so that overlay specifications can be developed for the next VICAR processing step.

6. Remove vignetting from data by subtracting the logarithmic, absolute brightness version of each vignetting image from the logarithmic, absolute brightness version of each of its corresponding data images, and rescale absolute brightness levels in the resultant images using VICAR processor Diffpic.

7. Create unvignetted, photographic images using a Photowriter digital-to-photographic image converter, and produce tracings of absolute photometric value along selected paths using the VICAR processor Lplot.

8. Rescale unvignetted images using VICAR processor Stretch and output resulting images on the Photowriter to achieve best visual contrast of processed data for analysis and interpretation.

B. Numerical Computations

1. Measure the shape, centering and extent of diffuse, low brightness sources and determine brightness gradients in the scenes.

2. Establish position and variation in photometric measurements of source versus time, and determine importance to its prior appearance, background and foreground light, and vector distances from sun, moon, stars and planets.

3. Compare color brightness measurements to each other and to brightnesses in unpolarized and polarized white light, develop ratios and plot results versus celestial position.

4. Cross-coordinate analyses and interpretations with gegenschein (S-178) and solar corona (S-210/212) images.

Table 5

5. Relate, analyze and interpret photometric measurements with results from other investigations that have produced photographic and photoelectric brightness measurements.

6. Compute orbital elements and recent history of motions for nearby, interplanetary dust particles or groups of light-scattering particles that produce some of these phenomena including the effects of solar radiation pressure, Poynting-Robertson and gravitational perturbations from the sun and large planets.

C. Isophote Map Production

1. Smooth emulsion grain noise levels in digital arrays of processed image data.

2. Convert smoothed image arrays to inputs for automatic contour plotting programs, specify output contour values, and produce plot tapes.

3. Create isophote maps of individual frames, review output, rework input data for plots as necessary, replot and analyze results.

4. Average and smooth regions of overlap in data, and create isophote maps for mosaic arrangement.

D. Clipping of Stars

1. Produce a smoothed brightness map of each unvignetted data image through repeated expansion-contraction use of VICAR processor Geom, then subtract this brightness map from its unvignetted data frame using VICAR processor Diffpic to define positional correspondence and relative brightnesses of stars above the foreground source.

2. Iterate the previous step as necessary to adjust and refine accuracy in stellar brightness values of the star map array.

3. Use VICAR processor Diffpic to subtract the star map array from its unvignetted data scene.

4. Smooth noise in resulting image using appropriate VICAR processors in order to simplify measurement, analysis and interpretation of low brightness, astronomical source.

E. Removal of Smear

1. Examine unvignetted data frames for smear using the geometry and density characteristics of stellar images, i.e., linear, broken-line or circular patterns and uniform, constantly varying or uneven densities.

2. Classify each smeared data image by the importance of scientific value versus complexity of smear pattern.

3. Determine the simplest orientation procedures and the number of collapsing convolutions required along a rectilinear or rotational coordinate to reduce smeared stars to approximate point sources.

4. Use VICAR processors Geom and FFTFil (Fast Fourier Transform Filter) to obtain an unsmeared image.

5. Clip resulting stellar images, smooth final image array and produce Photowriter output.

Table 5 Concluded

lists of which files on which computer tapes contain which version of the image. Because of iterative steps, the number of image arrays on tape files can multiply rapidly with many different versions relating to a single data frame. Processing of the four-minute exposure of lunar libration region L_4 from Apollo 15 shows both the elegance and the complexity of this work. Figure 9 gives pictorial results from the Photowriter of some of the steps covered under Part A, Basic Image Processing, in Table 5, and each digitized image is accompanied by its histogram. The data frame and its calibrations were digitized using a thirty-six square micron aperture, while its vignetting frame used a forty micron square aperture; so, adjustments had to be made during VICAR processing.

Step 1 Unprocessed VICAR format reconstruction of L_4 frame.

Step 2 L_4 image with base plus fog density removed.

Step 4 Log absolute brightness of density for L_4 image

Step 5 Unprocessed VICAR format reconstruction of Apollo 15 35mm Nikon and 55mm, f/1.2 lens vignetting frame.

Step 6 Size expansion of vignetting image using VICAR processor Geom which generated extra "pixels" with assigned values computed by averaging adjacent brightnesses and, in so doing, automatically performed a smoothing operation on the new image.

Step 7 Typical calibration step wedge for determining values of density versus log brightness for the vignetting frame; a similar step wedge image, not shown, would represent Step 3 in the processing chain for the L_4 data frame.

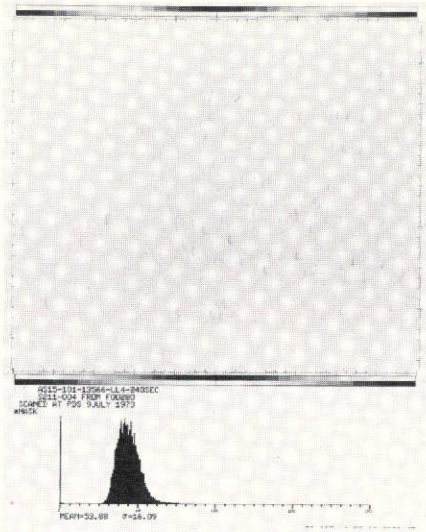
Step 8 Log absolute brightness of density for lens vignetting image.

Step 9A Unvignetted L_4 image in log absolute brightness created by VICAR processor Diffpic differencing the image in Step 8 from the image in Step 4 and rescaling brightness levels.

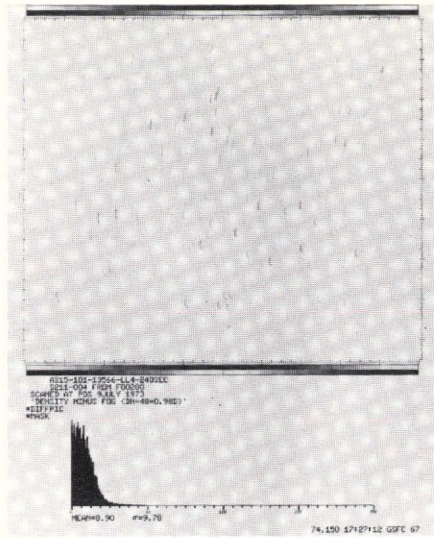
Step 9B Doubled log brightness values of unvignetted L_4 image in Step 9A.

Step 9C Quadrupled log brightness values of unvignetted L_4 image in Step 9A which provides a more useful visual presentation for measurements, analysis and interpretation of results.

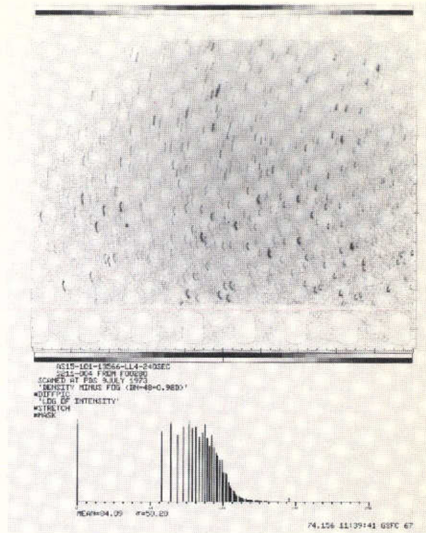
Figure 10 was created on an Antech color television display device that presents operator-controlled, color-coded brightness levels to aid in analyses. The scene on the left is a color-coded version of Step 4 in Figure 9. The center view is the color version of Step 8, and the view on the right is the color version of Step 9C. Although there was some "blooming" in the picture which distorts the brightness relationships in the horizontal direction, it does define the L_4 region for further study. Figures 9 and 10 show how VICAR can be used to purposely enhance the scene while the true brightness information is preserved. This contrast-stretching capability is quite valuable for creating data formatted for best interpretation by the eye. Unfortunately, it purposely disregards the fidelity of true scene brightnesses or ratios of brightnesses. Work performed under this contract had to use the opposite em-



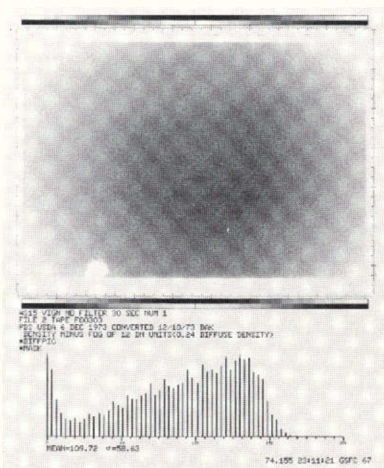
Step 1



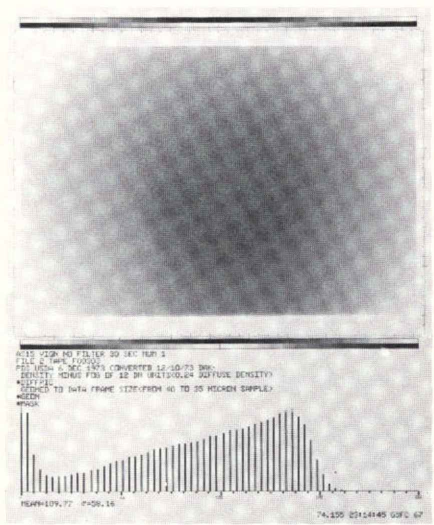
Step 2



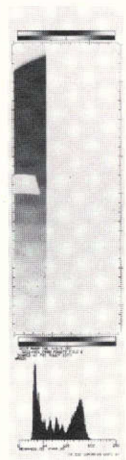
Step 4



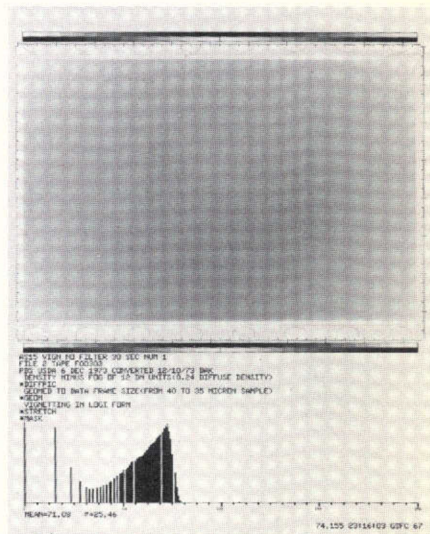
Step 5



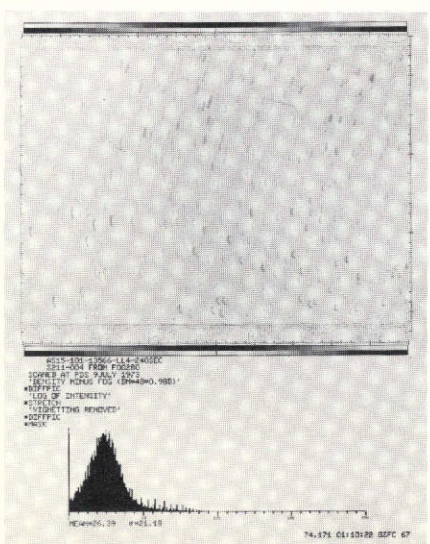
Step 6



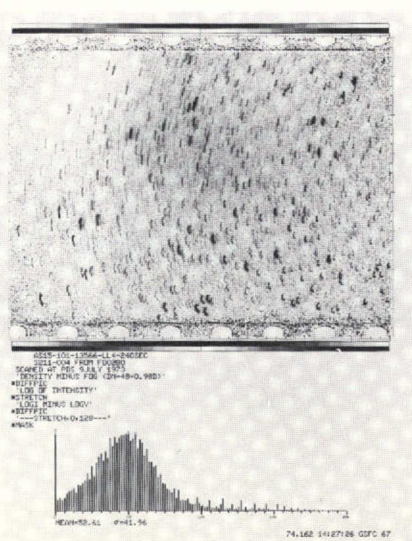
Step 7



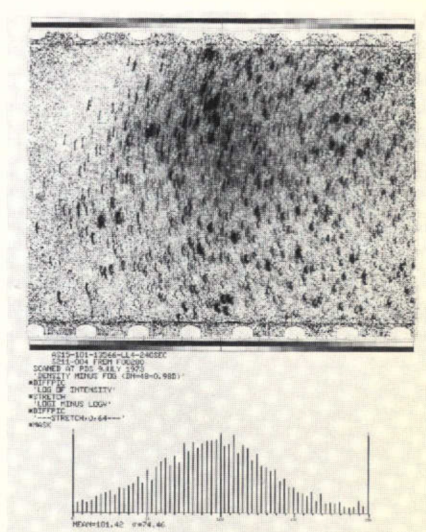
Step 8



Step 9A



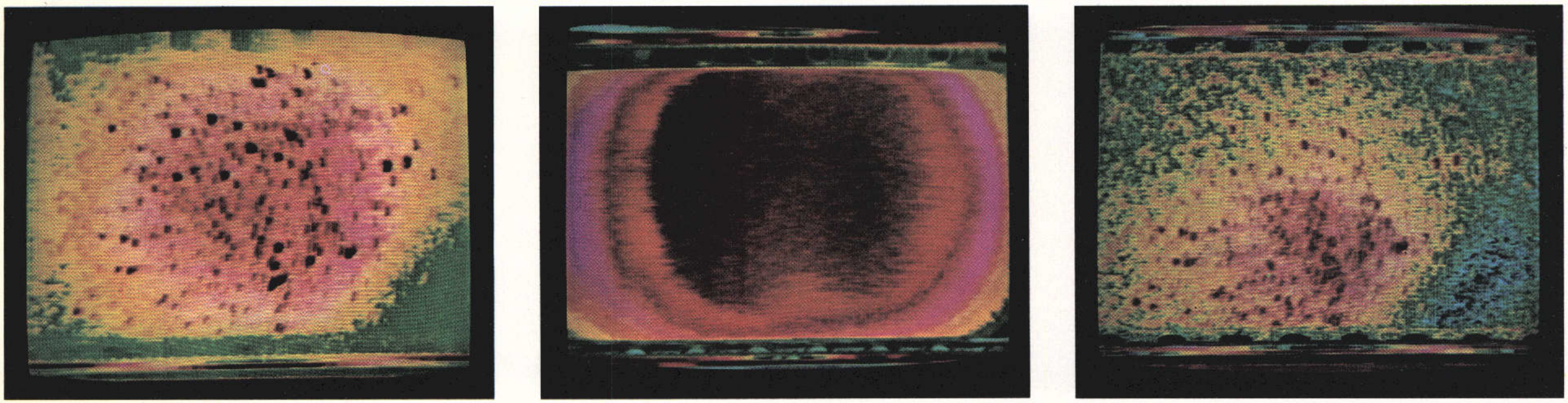
Step 9B



Step 9C

Figure 9

COLOR-CODED DENSITY LEVELS OF DIGITAL-COMPUTER-PROCESSED IMAGE FROM APOLLO 15 LUNAR LIBRATION REGION L_4 PHOTOGRAPHY



A gravipotential point of quasi-stability located sixty degrees ahead of the moon in its orbit and known as lunar libration region L_4 was photographed from the Apollo 15 spacecraft on July 31, 1971. Local interplanetary dust grains may accumulate, or at least linger, in such regions, and if particle accumulations could become sufficiently dense, then sunlight scattered by them would create a very faint, diffuse brightness in the sky. So, a series of four, white-light photographs of the L_4 region were made by Astronaut Alfred M. Worden from the lunar orbiting Command Module while it was shadowed by the moon both from sunlight and from earthshine. The longest photograph of this series, a four-minute exposure, was photodigitized and then processed on the NASA Goddard Space Flight Center's IBM 360/75 computer using the Video Image Communications And Retrieval (VICAR) software developed by NASA's Jet Propulsion Laboratory. The original photograph was taken with a 35mm Nikon camera using an f/1.2 lens working at maximum aperture and recorded on Eastman Kodak type 2485 emulsion. The camera was mounted behind the right-hand rendezvous window. A special shade isolated the camera lens and window panes from internal cabin lighting. Prior to the photography the spacecraft was automatically pointed by the attitude control system. A three-minute period of attitude rate damping followed the pointing maneuver; then, all attitude control thrusters were deactivated so that no extraneous sources of light would illuminate effluent particles from the spacecraft that might be in the camera's line-of-sight. The images on the left and right are centered approximately twelve degrees west of the Vernal Equinox near the ecliptic, and celestial north is slightly to the left of the upward direction. At the moment of exposure this celestial region had an ecliptic elongation of one-hundred forty degrees west; so, the zodiacal light background brightness was at a minimum. The view on the left shows relative brightnesses within the digitized version of the original data frame. The large aperture setting required to record faint, diffuse light sources creates a roughly symmetrical vignetting pattern. The middle image is the computer version of a photodigitized vignetting frame from the flight lens obtained by photographing a uniformly illuminated reflective screen. The presentation on the right is the resultant image after the emulsion base plus fog background of 8×10^{-15} of sun surface brightness has been removed and a compensating correction for the lens vignetting pattern shown above has been applied to the original data frame. The enhanced region that remains is approximately twice the background level or 1.5×10^{-14} of sun surface brightness. The lower right corner of the images on the left and right are portions of the field-of-view blocked by unavoidable spacecraft structure just outside the window.

Figure 10

phasis and take great pains to preserve quite accurately the brightness (Alvord et al, 1975). This has kept the pace slow and deliberate for the initial data processing. Quality, in terms of photometric accuracies, is the ultimate goal of this data analysis effort. Where the brightnesses are just on the threshold of detectability, the absolute error bars increase rapidly. This, in turn, has great influence on determinating the extent of limits for vague, ragged-edged phenomena. Out of all the data frames now available, only a few of the Apollo 15 frames have progressed to the stage of corrected brightnesses across their celestial scenes.

Other Computer Processing

Besides the brightness computations, computer programing has been started, but results have not yet been forthcoming, on two other parts of the work. The first of these is the VIEWS Program obtained from JSC. When this program is supplied with an appropriate state vector, look angle and field-of-view specifications, it will compute instantaneous celestial coordinates, and it then plots stars, planets and surface features of earth or moon that fall into the field-of-view. The program is actually a synthesis of several, individual subprograms in which each part takes as its input the output of the preceding part. Thus, a given state vector is integrated forward or backward in time by a Lunar Trajectory Module (LTM) to the moment of interest where look angle and field-of-view specifications are supplied. Limiting coordinates of the scene are developed so that a library of star and planet positions and magnitudes can be searched and those objects falling within the scene are converted to plot coordinates. Finally, if either the earth or moon is in view, an orthographic projection of vector segments showing surface details is added and occulted stars removed. An option is available to add celestial, geographic and/or selenographic coordinate lines as well. The computer program which performs these searches and calculations finally produces a magnetic plot tape for use on a Stromberg Carlson 4060 Plotter. Digital values on this tape drive both scan and intensity circuits of a cathode ray tube to produce the final plots for recording on microfilm.

It was intended to use the VIEWS Program to make celestial overlays to match important data frames. While checkout of the program did reach the stage where plot tapes were produced, the need for this type of data was considered less important than checkout of the VICAR Program software; so, no overlays have been developed. The LTM routine was used separately, however, in an attempt to compute the instantaneous position of the lunar libration point L_4 with solar and planetary perturbations included. Results from Apollo 15 of the four-minute exposure in the direction of L_4 made this supporting computation important. But, after several weeks work, it was clear that the LTM program could not be used in this way. A second computer program using a Double-Precision Trajectory (DPTraj) routine was obtained and checked out for this work. Several weeks were needed to tailor it to the L_4 problem, and here again, such work had to cease so that the computer consultant, Mr. Alvord, could help with the VICAR processing. The extent to which the effort had grown also indicated that it would be better to delay further computations on the L_4 point until the data frame had been processed and analyzed to assure that publishable data was obvious on the film.

PHOTOGRAPHIC COVERAGE, QUALITY AND FORMAT

Photographic coverage has already been summarized in Tables 3 and 4. Detailed coverage and format listings of low brightness, astronomical and related photography for Apollos 14 through 17 are presented in Appendices A through D, respectively. Figures 2 through 5 show representative examples of data quality. A judgment on quality is highly dependent on the intended use of the data. For low brightness, diffuse phenomena where edge densities are quite gradual, the graininess of the film does not present any difficulties. However, future investigators would find these scenes useless for astrometry, although a search for point sources might prove fruitful, if the source can be clearly differentiated from grain noise.

Appendix E is a listing of photodigitized flight data frames and flight calibrations frames including their current file and tape locations at GSFC. These relate subject matter to flight, date and time, flight magazine designation (MgDg), quick-look number (QL No), NASA frame number, camera type and format, center-of-frame coordinates, tape designations and file numbers of the PDS and VICAR digitized image arrays, the number of scan lines (Numb Line), number of samples per line (Numb Samp), notation as to the existence of Dicomed (DM) photodigitized versions and computer processed versions continued beyond the first stage (Cn). The last page of Appendix E gives some information on the vignetting data and their calibration frames, although this tabulation is not yet complete.

The PDS data is recorded on 9-track, 800 bits per inch, odd parity magnetic tapes with file and inter-record gaps that are IBM-compatible. Starting from the reference edge of the tape the nine data bit channels have the order 5,7,3,Parity, 2,1,0,6 and 4, but tracks 0 and 1 for each character are not used in the 9-track tape format. The first record in each file consists of two tape characters representing the octal number 7777. These are used for recognizing the beginning of a file and are not part of the data-related information. The second record has eighty characters in ASC II code representing forty 12-bit words of identification information. Each pair of characters represent the binary value for an octal number which, when algebraically added to -8000_8 gives the negative of the number of data values following the coordinate information in the record. Each data word is made up of two six-bit tape characters. Thus, $(110000)(000000)_2 = 6000_8$ which corresponds to $-2000_8 = -1024_{10}$, signifying 1024 digitized samples per scan line. The fourth record is four six-bit characters of the x-coordinate in microns where data taking begins for the current scan line, and the most significant bit is a sign bit with zero equal to positive and one equal to negative. If the number is positive, it is read directly, i.e. $(000000)(000010)(011100)(010000)_2 = 00023420_8 = 10000_{10}$ microns; if it is negative, its 2's compliment incremented by an octal "one" is the negative value in microns, i.e. $(111111)(111101)(100011)(110000)_2 = -00023420_8 = -10000_{10}$ microns. The fifth record is represented in just the same way as the fourth record, but it gives the y-coordinate in microns where data taking begins. The sixth record represented like the previous two gives the x-distance between readings, i.e. the sampling step size or delta-x of travel between readings. The seventh and final record in the file is a continuous string of six-bit character pair words and each word forms a photometric reading in terms of 0.0025 of a density unit, i.e. $(000111)(110100)_2 = 0764_8 = 500_{10}$ which represents 500 x 0.0025 = 1.25 density value.

An inter-record gap follows each record, and the file made up of these records provides all the information for a single line scan by the photometer. At the end of the string of files which make up the entire frame scan there is a double file gap which is recognized as an End-of-File (EOF) mark.

PDS data conversion to VICAR format produces a 9-track tape with odd parity packed 1600 bits per inch on the GSFC IBM 360 system. For VICAR formatting the user must input for each file, i.e. for each scanned image, identification and header information which can be any length up to 360 characters. This will be recorded as Binary Coded Decimal (BCD) characters, and these are taken from the first 71 columns of up to five input data cards per image following the conversion program deck. The information on these cards forms the first record of the VICAR image file, and the first six records of the corresponding PDS image file are discarded. Since no identification or coordinate specification data from PDS is carried over to VICAR arrays during reformatting, the user must save any such pertinent data he requires by entering it into the VICAR identification and header cards. The VICAR records subsequent to this identification record are strings of eight-bit numerical characters corresponding to the individual density readings along a scan line, and consecutive records represent consecutive lines in the scan. The source for each record is the seventh and last record in each consecutive PDS file for that image until the EOF mark is reached. Since PDS film density data are numerical values of 2^{10}, the last two least significant bits are rounded and discarded during the conversion of each PDS character pair to a single VICAR character with numerical value of 2^{8}. While this reduces the reading resolution from 0.0025 to 0.01 of a density unit, it is quite sufficient for the type 2485 emulsion where grain noise can create uncertainties to 0.02 of a density unit. Also, since the PDS scans the image back and forth, the readings in the seventh, or data, record of every other PDS file are written out in reverse order during conversion so that the VICAR image array scans all appear to be in the same direction.

DISCUSSION OF RESULTS

Information presented above shows that only a small portion of the data have reached the end point in processing, analysis and interpretation. Comparison of Table 2 with Table 4 indicates that only the earth atmospheric scattering study using the lunar eclipse is complete, with results given in Figure 3. The black-and-white photography of the moon in full eclipse was not successful because the amount of light that reached the moon was considerably more than expected, and the excessively halated lunar image appeared three times its normal size.

Although L_4 analysis and interpretation is not complete, substantive information is quite apparent from Figures 9 and 10 and just whets the scientific appetite to carry processing of this image as far as possible. A noteworthy fact has emerged within the past few weeks that further elevates the importance attached to this Apollo 15 L_4 data. On Skylab 3 several 35mm Nikon photographs in the direction of the gegenschein included a portion of the very same celestial field in which the unvignetted L_4 data frame from Apollo 15 shows an obvious enhancement. However, at the time of the Skylab photograph no libration region should have been in the camera's field-of-view, although the gegenschein was several degrees away. These particular Skylab 3 frames, and 16mm flight calib-

rations that can be related to them, have also been digitized and converted to VICAR format as a part of the Experiment S073 data reduction task. Further analysis of these Skylab frames in conjunction with the Apollo 15 results may produce the most conclusive observational information ever recorded on this phenomenon. It is also fortunate that the L_4 region, as photographed from lunar orbit, had a solar elongation of about 140° where the zodiacal light background has its minimum brightness, so that the signal-to-noise was ideal.

The phenomenon appears at the proper position along the lunar orbital plane but some eight degrees south. If it is near one corner of an equilateral triangle with the earth and moon at the other corners, that would place it over 30,000 miles below the unperturbed gravipotential minimum position, which is an order of magnitude further out of plane than theoretically discussed by Michael (1963), and this may explain why previous observations (Roach et al., 1973 and Munro et al., 1975) cannot show consistent locations. It certainly justifies a continuation of particle trajectory calculations using the DPTraj program to discover limitations in the theoretical predictions of the extent and location of this phenomenon.

The reason for such a deviation may be speculated in terms of the lunar orbital plane's ascending node with respect to the ecliptic and a history of lunar umbral position over several days preceding the Apollo 15 photography. The smallest particles either orbiting the moon or secondary ejecta in high parabolic trajectories will be further accelerated away from the sun by photon pressure. The motions of such particles would range from suborbital, ballistic trajectories through ever increasing eccentric orbits of the moon to hyperbolic escape trajectories. But in all cases the major axis should generally be inertial and take on alignments tending to parallel the lunar umbral direction with their apolunes down-sun. Such an anti-solar streaming effect would have caused particles to pass by and below the gravipotential capture region about three days prior to the L_4 photography. Some of those near apolune at the L_4 distance entering the umbra would temporarily be relieved of solar pressure acceleration. Since some would have very low residual velocities with respect to the L_4 region, they could be loosely captured in an orbital plane different from the lunar plane. This accumulation could persist for a short while before perturbing gravitational forces of the sun and other planets as well as renewed solar photon pressure would eventually disperse the particle cloud. Helpful conditions for accumulation are further suggested to a first approximation by the planetary geometry that existed at the time; however, a proof of this must await results from a thorough analytical study of the force field and associated trajectories.

Zodiacal light photography provided the most extensive results by far and included more than one-hundred twenty frames. About half of these in white, red, blue and polarized light from Apollos 15 and 17 are of excellent quality with good calibration data. In addition, there are several more frames, taken with the Hasselblad for S-210/212 to define coronal structure, that can be examined to within tenths of a degree of the solar surface. All of this photography represents one of the most extensive surveys of zodiacal light yet performed and certainly under the finest observing conditions. Only a very few of the Apollo 15 frames have been carried beyond the VICAR formatting stage of processing, and some will require extensive computer work to remove smear and starlight prior to the build-up of mosaic isophote maps. Some calibration

exposures to remove reciprocity effects between photographed brightness standards and data did not include steps of appropriate surface brightnesses to cover the entire range of density levels present in the data; so, a fraction of the data may lack absolute calibration values. However, absolute accuracies over most of these data should be about 20%, and brightness relationships to data out of the absolute calibration range should permit relative measurements to 10%, if levels are not too close to background or too high, so that final accuracies across the frame should be within 40%. Also, the coverage of zodiacal light in broad band white light and two colors will permit the comparisons necessary to infer particle size distributions and the types of materials present in the interplanetary dust (Giese et al., 1973). In addition, these zodiacal light photographs will compliment the large amounts of photoelectric photometry already obtained by many investigators (Weinberg, 1967) and continuing to be collected using interplanetary probes (Hanner et al., 1974).

The opportunity arose during the earth-orbiting Skylab 3 and 4 missions to obtain additional 35mm Nikon, long duration exposures on type 2485 film of zodiacal light, gegenschein, libration regions, diffuse galactic sources, etc. The quality of scientific content in such photographs was expected to exceed the Apollo data because of the much greater stability for the Skylab vehicle over Apollo. This would eliminate smear in the images, although the avoidance of airglow and reflections of unavoidable sources from the outer structure of the vehicle were complications that were not a factor in the Apollo data. Unfortunately, the sixty-two data frames taken on Skylab 4 are completely out of focus because the film backing plate had become separated from the camera. The effective focal lengths varied across the field in the range of two to five feet; this created 1.2mm to 1.5mm diameter disks for stellar point sources. Five exposures of the gegenschein on Skylab 3, with the longest exposure at five and one-half minutes, were of good quality, and can be reduced. But, there is no question that the Apollo low brightness, astronomical studies now represent the highest quality and most extensive photographic data of zodiacal light currently available for study. It now appears that the opportunity to improve upon these data will not be available again for at least a decade.

New information on the Gum nebula will probably not result from the two scenes of color photographs from Apollo 16; however, further reduction and analysis may establish upper limits on the emission brightnesses of the ionized gas components. It appears that the suppression of the Milky Way background by filtering may have taken its toll on the signal strength of the theoretically postulated emission lines, as well. The white light photographs of the Milky Way from Apollo 15 will be useful for comparison with absolute brightness measurements from ground-based photographic and photoelectric measurements of diffuse galactic light that could not avoid airglow and atmospheric effects. The galactic pole photography from Apollo 14 may be of some additional help in this matter as well as in zodiacal light coverage; however, the lower overall quality resulting from smaller celestial size versus film grain in the Apollo 14 data dictates that further reduction of this be given last priority or even omitted if continued data reduction efforts must be kept small. Apollo 14 photographs of the earth's darkside and the S IV B stage were not successful, and no data reduction effort should be expended on these frames.

CONCLUSIONS

1. The lunar libration region L_4 four-minute photograph from Apollo 15 is of excellent quality. The existence of additional space photography from Skylab 3 of the same region, but without the presence of the libration region, will add greatly to the value of this scientific study. Absolute photometric accuracies should be approximately 25% for this very low brightness source. Image smear is moderate, and extensive processing to remove this and stellar images will not be required to obtain useful measurements of the phenomenon. The large deviation in position out of lunar plane is particularly unexpected and should be further studied in order to discover the important sources of particle-accumulating mechanisms.

2. The vast amount of zodiacal light photography is now available for analyses on both an individual frame basis and by the collective relationship of exposures within and between series. In regard to the latter, comparisons between color, white light and polarization measurements of the same region photographed three times on Apollo 17 will be of considerable scientific value for theoretical models. An analysis of the non-structural, solar F-corona regions in photography obtained for experiments S-210/212 will provide additional information on the overlapping region of the corona and zodiacal light continuum to about one solar radius of the photosphere. Because of the quantity of data available, the zodiacal light processing and analysis could utilize eight to ten man-years of effort; however, publishable data would be forthcoming at various intervals throughout the work and a level-of-effort approach to the data reduction task could prove valuable.

3. Galactic light and Gum nebula data processing could be continued on a low priority basis or, more preferably, carried out intermittently during the processing of zodiacal light data when scheduling of computer or image display facilities causes delays in work on primary objectives. Whether such processing and analyses should continue is a matter of funding and scientific priorities within this discipline as well as the scheduling of the necessary GSFC facilities. This work should definitely not be allowed to interfere with or affect funding for continued data reduction and analysis of the L_4 region and zodiacal light photography. The scientific results to be gained for galactic light and the Gum nebula photographs are unknown, and the ultimate photometric accuracies achievable are probably not better than 50%.

4. Photography of the earth's darkside and the S IV B were unsuccessful, and no further work with these data is justified.

5. Color photography of the lunar eclipse was successful, and the data have been analyzed and interpreted as presented in Figure 3. The type 2485 exposures were unsuccessful with respect to measurements of lunar surface brightness in the earth's shadow; however, these frames do provide photographic evidence that the vicinity of the spacecraft in coasting, transearth orbit is almost devoid of effluent particles.

RECOMMENDATIONS

1. Image processing of the four-minute lunar libration photograph and its companion Skylab 3 photograph should be continued. In addition, analytical studies of the gravitational force field and particle trajectories specifically related to solar system geometry that existed and just preceded the time of the Apollo 15 photography should commence.

2. Image processing and analysis of zodiacal light should be continued on at least a level of effort basis, preferably with a scientific investigator part-time and a computer assistant full-time as a minimum effort. Processing should be accomplished on the GSFC IBM 360 computers both on site and by remote terminal. A plan for reporting and publishing results should be established whereby frames requiring the least processing would be studied first and the more complex relationships reserved until later. This approach would insure scientific output and justify further continuance of the work, especially if such efforts should be funded at a low but continuing level. Any attempt to push the work at a rate exceeding about four man-years per year would lead to diminished productivity because of uncontrollable lag time involved in computer and image display processing and the use of shared government facilities.

3. Image processing and analysis of galactic light and Gum nebula should not be continued unless they can be conveniently included with similar zodiacal light work in such a way that cost and effort are kept to a minimum.

4. No further processing or analysis should be performed on the earth's darkside photographs, the attempted S IV B photographs, or the low brightness photographs of the moon in eclipse.

LIST OF ACRONYMS AND ABBREVIATIONS

APST	Apollo Lunar Orbital Photographic Science Team
BCD	Binary Coded Decimal digital computer characters
Br	Bracket for mounting cameras
CDR	Commander
CM	Command Module
CMP	Command Module Pilot
Co-I	Co-Investigator
COSPAR	Committee on Space Research
Cn	Digital computer image processing continued
CSM	Command and Service Modules of the Apollo spacecraft
DAC	16mm Data Acquisition Camera
DM	Dicomed photodigitization
DPTraj	Double-Precision Trajectory digital computer program
EOF	End-of-File mark
ERTS	Earth Resources Technology Satellite
GSFC	Goddard Space Flight Center
HAO	High Altitude Observatory, National Center for Atmospheric Research, Boulder, Colorado, 80302
HEC	70mm Hasselblad electric camera
IBM	IBM computers
ISSR	Institute for Scientific and Space Research, Inc., Delmar, New York, 12054
IUE	International Ultraviolet Explorer satellite
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LTM	Lunar Trajectory Module digital computer program
MgDg	Flight magazine designation
mm	millimeter = 10^{-3} meter
nm	nanometer = 10^{-9} meter
NASA	National Aeronautics and Space Administration
NK	35mm Nikon camera
Numb Line	Number of scan lines in photodensitometered image
Numb Samp	Number of discrete samples per scan line in photodensitometered image
PC	Power cable for DAC
PDS	Photometric Data Systems Division of Perkin Elmer Corporation
PI	Principal Investigator
PTD	Photographic Technology Division at JSC
QL No.	Quick Look identification list number
RC	Remote cable for DAC shutter speed and actuating switch control
RM	Right angle mirror for DAC
S IV B	Third stage of the Apollo Saturn launch vehicle
Sh	Window Shield
Sprt Equip	Supporting Equipment
VICAR	Video Image Communication and Retrieval digital computer program
VIEWS	VIEWS composite digital computer program

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APPENDIX A

APOLLO 14 LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY

Apollo 14 photographic data for these studies was recorded on Magazine J loaded with Eastman Kodak type 2485, high-speed, black-and-white film, emulsion number 26-1, using a 16mm Data Acquisition Camera and an 18mm, f/0.95 (T/1.00) lens. This provides a field-of-view of 32.6° by 23.4° with a 39.2° diagonal. The film was calibrated for long exposures using a low brightness, nine-step reflectance chart illuminated by a nine lambert, diffuse source perpendicular to and two meters from the chart. Calibration photographs were made two meters from the target and 20° off the normal.

Frames on the film strip from Magazine J were not given individual NASA frame numbers, because data obtained on the 16mm DAC film is not generally recorded in the single framing mode of operation. Since the DAC with 25mm lens provided the fastest camera system on board the spacecraft, it was used extensively in this mode of operation for the low brightness, astronomical photography. Therefore, a Quick-Look number has been assigned to each frame. All low brightness photography except through the sextant was performed with the lens set on T1, i.e. f/0.95, and focus at infinity. When the DAC is used with the sextant, the lens is omitted and an adapter sleeve is employed. In this configuration the effective focal length is about 216mm at infinity providing a two-degree, circular field-of-view. The camera-sextant aperture is about f/8, but beam splitters further reduce the available light by a factor of four.

All times are given to the nearest minute. The centers of frames (Cntr Frm Loc) and corners of frames (Crnr Frm Loc) are given in the tables when stellar patterns are sufficiently bright for comparison to star charts, or when weak image patterns may be reliably inferred by comparison to data in adjacent frames. Protect frames refer to either individual or a series of frames at shutter speeds of 1/1000. These spacings protect data frames by winding them through onto the take-up spool where they will not be affected by unintentional fogging from sunlight or other bright sources leaking past the shutter.

These tables also include exposures for Experiment S-178 Gegenschein/Moulton Region Photography.

NASA Magazine No AS 14 | Magazine Flight Designator J

Film Type 2485 | Film Size 16 mm

Quick Look Begin Fr No	Quick Look End Fr No	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
0000	0001	Mag Film Loading	26 Jan.1971	0400	-	-	-	-	-	
0002	0015	Protect Frames	" " "	-	-	-	-	-	-	
0016	0020	" "	" " "	-	-	-	-	-	-	Orig. Removed for S-178,3/12/71
0021	-	Calibration Frame	" " "	0431	60	-	-	-	-	" " " " "
0022	0023	Protect Frames	" " "	0432	-	-	-	-	-	" " " " "
0024	-	Calibration Frame	" " "	0432	20	-	-	-	-	" " " " "
0025	0026	Protect Frames	" " "	0432	-	-	-	-	-	" " " " "
0027	-	Calibration Frame	" " "	0432	5	-	-	-	-	" " " " "
0028	-	Protect Frame	" " "	0433	-	-	-	-	-	" " " " "
0029	-	Protect Frame	" " "	0433	-	-	-	-	-	
0030	-	Calibration Frame	" " "	0433	60	-	-	-	-	
0031	0032	Protect Frames	" " "	0434	-	-	-	-	-	
0033	-	Calibration Frame	" " "	0434	20	-	-	-	-	
0034	0035	Protect Frames	" " "	0434	-	-	-	-	-	
0036	-	Calibration Frame	" " "	0434	5	-	-	-	-	
0037	0069	Protect Frames	" " "	-	-	-	-	-	-	
0070	0084	First Mag Removal	" " "	-	-	-	-	-	-	
0085	0248	NASA PTL Identification	" " "	0500	-	-	-	-	-	
0249	0264	Second Mag Removal	2 Feb.1971	-	-	-	-	-	-	
0265	0306	Protect Frames	" " "	-	-	-	-	-	-	
0307	-	Earth Darkside, through Sextant	" " "	0351	60	-	-	-	-	
0308	-	" " "	" " "	0352	20	-	-	-	-	
0309	-	" " "	" " "	0352	5	-	-	-	-	
0310	-	" " "	" " "	0353	60	-	-	-	-	
0311	-	" " "	" " "	0354	20	-	-	-	-	
0312	-	" " "	" " "	0354	5	-	-	-	-	
0313	0347	Protect Frames	" " "	-	-	-	-	-	-	
0348	0353	Third Mag Removal	" " "	-	-	-	-	-	-	
0354	0423	Protect Frames	" " "	-	-	-	-	-	-	
0424	-	S IV B	" " "	0705	60	-	-	-	-	
0425	-	"	" " "	0706	20	-	-	-	-	
0426	-	"	" " "	"	5	-	-	-	-	
0427	0468	Protect Frames	" " "	-	-	-	-	-	-	
0469	0474	Fourth Mag Removal	" " "	-	-	-	-	-	-	
0475	0508	Protect Frames	" " "	-	-	-	-	-	-	
0509	-	S IV B	3 Feb.1971	0602	60	-	-	-	-	

NASA Magazine No AS 14 Magazine Flight Designator J

Film Type 2485 Film Size 16 mm

Quick Look Begin Fr No	Quick Look End Fr No	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
0510	-	S IV B	3 Feb.1971	0603	20	-	-	-	-	
0511	-	"	" " "	"	5	-	-	-	-	
0512		"	" " "	0604	50	-	-	-	-	
0513	0554	Protect Frames	" " "	-	-	-	-	-	-	
0555	0557	Fifth Mag Removal	" " "	-	-	-	-	-	-	
0558	0561	" " "	" " "	-	-	-	-	-	-	Orig. Removed for S-178,3/12/71
0562	0670	Protect Frames	" " "	-	-	-	-	-	-	" " " " "
0671	-	Gegenschein	5 Feb.1971	1226	20	$8^h\ 45^m$	$+22^o$	$9^h\ 15^m$	$+33^o$	" " " " "
0672	-	"	" " "	"	"	$8^h\ 50^m$	$+22^o$	$9^h\ 15^m$	$+34^o$	" " " " "
0673	-	"	" " "	"	5	$8^h\ 50^m$	$+22^o$	$9^h\ 15^m$	$+34^o$	" " " " "
0674	-	"	" " "	1227	"	$8^h\ 50^m$	$+24^o$	$9^h\ 20^m$	$+35^o$	" " " " "
0675	-	"	" " "	"	20	$8^h\ 50^m$	$+23^o$	$9^h\ 15^m$	$+33^o$	" " " " "
0676	-	"	" " "	"	5	$8^h\ 50^m$	$+23^o$	$9^h\ 15^m$	$+33^o$	" " " " "
0677	-	"	" " "	1232	20	$9^h\ 05^m$	$+22^o$	$9^h\ 25^m$	$+35^o$	" " " " "
0678	-	"	" " "	"	"	$9^h\ 10^m$	$+23^o$	$9^h\ 25^m$	$+36^o$	" " " " "
0679	-	"	" " "	"	5	$9^h\ 10^m$	$+25^o$	$9^h\ 30^m$	$+37^o$	" " " " "
0680	0770	Protect Frames	" " "	"	-	-	-	-	-	" " " " "
0771	-	Gegenschein	" " "	1237	20	$9^h\ 20^m$	$+23^o$	$10^h\ 05^m$	$+31^o$	" " " " "
0772	-	"	" " "	"	"	$9^h\ 20^m$	$+23^o$	$10^h\ 10^m$	$+32^o$	" " " " "
0773	-	"	" " "	"	5	$9^h\ 20^m$	$+23^o$	$10^h\ 10^m$	$+31^o$	" " " " "
0774	0853	Protect Frames	" " "	"	-	-	-	-	-	" " " " "
0854	-	Gegenschein	" " "	1242	20	$10^h\ 00^m$	$+13^o$	$11^h\ 00^m$	$+24^o$	" " " " "
0855	-	"	" " "	"	"	$10^h\ 00^m$	$+13^o$	$11^h\ 00^m$	$+24^o$	" " " " "
0856	-	"	" " "	"	5	$10^h\ 05^m$	$+14^o$	$11^h\ 00^m$	$+26^o$	" " " " "
0857	-	"	" " "	1243	10?	$10^h\ 05^m$	$+13^o$	$11^h\ 00^m$	$+26^o$	" " " " "
0858	0894	Protect Frames	" " "	-	-	-	-	-	-	" " " " "
0895	0897	Sixth Mag Removal	" " "	-	-	-	-	-	-	
0898	0901	" " "	" " "	-	-	-	-	-	-	
0902	0961	Protect Frame	" " "	-	-	-	-	-	-	
0962	-	Zodiacal Light		1428	4?	-	-	-	-	Star Field too weak
0963	-	" "	" " "	"	5	$2^h\ 55^m$	$+15^o$	$3^h\ 20^m$	$+24^o$	
0964	-	" "	" " "	"	20	$2^h\ 55^m$	$+15^o$	$3^h\ 20^m$	$+24^o$	
0965	-	" "	" " "	"	5	$2^h\ 55^m$	$+15^o$	$3^h\ 20^m$	$+24^o$	
0966	-	" "	" " "	1429	4?	-	-	-	-	Star Field too weak
0967	-	" "	" " "	"	16	$2^h\ 45^m$	$+14^o$	$3^h\ 10^m$	$+24^o$	
0968	-	" "	" " "	"	8	$2^h\ 40^m$	$+14^o$	$3^h\ 10^m$	$+24^o$	

NASA Magazine No AS 14 Magazine Flight Designator J

Film Type 2485 Film Size 16 mm

Quick Look Begin Fr No	End Fr No	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
0969	-	Zodiacal Light	5 Feb.1971	1430	20	$2^h\ 05^m$	+10°	$3^h\ 05^m$	+22°	
0970	-	" "	" " "	"	16	$2^h\ 05^m$	+11°	$3^h\ 05^m$	+23°	
0971	-	" "	" " "	"	4	$2^h\ 00^m$	+13°	$2^h\ 50^m$	+27°	
0972	-	" "	" " "	1431	16	$2^h\ 05^m$	+10°	$2^h\ 30^m$	+25°	
0973	-	" "	" " "	"	8	$2^h\ 05^m$	+10°	$2^h\ 30^m$	+25°	
0974	-	" "	" " "	"	1	-	-	-	-	Star Field too weak
0975	-	" "	" " "	"	4	-	-	-	-	" " " "
0976	-	" "	" " "	"	1	-	-	-	-	" " " "
0977	-	" "	" " "	1432	16	$1^h\ 20^m$	+08°	$2^h\ 10^m$	+19°	
0978	-	" "	" " "	"	8	$1^h\ 20^m$	+08°	$2^h\ 10^m$	+19°	
0979	-	" "	6 Feb.1971	"	1	-	-	-	-	Star Field too weak
0980	-	" "	" " "	"	"	-	-	-	-	" " " "
0981	-	" "	" " "	"	"	-	-	-	-	" " " "
0982	-	" "	" " "	"	"	-	-	-	-	" " " "
0983	-	" "	" " "	"	4	-	-	-	-	" " " "
0984	-	" "	" " "	"	1	-	-	-	-	" " " "
0985	-	" "	" " "	1433	"	-	-	-	-	" " " "
0986	-	" "	" " "	"	8	-	-	-	-	" " " "
0987	-	" "	" " "	"	2	-	-	-	-	" " " "
0988	-	" "	" " "	"	4	-	-	-	-	" " " "
0989	-	" "	" " "	"	1	-	-	-	-	" " " "
0990	-	" "	" " "	"	8	-	-	-	-	" " " "
0991	-	" "	" " "	1434	4	-	-	-	-	" " " "
0992	-	" "	" " "	"	1	-	-	-	-	" " " "
0993	-	" "	" " "	"	1	-	-	-	-	" " " "
0994	1066	Protect Frames	" " "	-	-	-	-	-	-	
1067	1079	Seventh Mag Removal	" " "	-	-	-	-	-	-	
1080	1124	Protect Frames	" " "	-	-	-	-	-	-	
1125	-	North Ecliptic Pole	" " "	1823	20	$17^h\ 50^m$	+68°	$19^h\ 50^m$	+58°	
1126	-	" " "	" " "	"	1	-	-	-	-	Star Field too weak
1127	-	" " "	" " "	1824	10	$18^h\ 00^m$	+67°	$20^h\ 00^m$	+58°	
1128	-	" " "	" " "	"	20	$18^h\ 10^m$	+68°	$20^h\ 00^m$	+58°	
1129	-	" " "	" " "	"	5	$18^h\ 00^m$	+68°	$19^h\ 00^m$	+58°	
1130	1179	Protect Frames	" " "	-	-	-	-	-	-	
1180	1188	Eighth Mag Removal	" " "	-	-	-	-	-	-	
1189	1249	Protect Frames	" " "	-	-	-	-	-	-	

Film Type 2485 Film Size 16 mm

Quick Look Begin Fr No	Quick Look End Fr No	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
1250	-	North Galactic Pole	6 Feb.1971	1009	20	$12^h\ 40^m$	$+27^\circ$	$13^h\ 30^m$	$+35^\circ$	
1251	-	" " "	" " "	"	"	$12^h\ 40^m$	$+27^\circ$	$13^h\ 30^m$	$+35^\circ$	
1252	-	" " "	" " "	1010	5	$12^h\ 40^m$	$+28^\circ$	$13^h\ 40^m$	$+38^\circ$	
1253	-	" " "	" " "	"	1	$12^h\ 30^m$	$+28^\circ$	$13^h\ 30^m$	$+38^\circ$	
1254	1316	Protect Frames	" " "	-	-	-	-	-	-	
1317	-	North Galactic Pole	" " "	1010	20	$12^h\ 35^m$	$+29^\circ$	$13^h\ 30^m$	$+40^\circ$	
1318	1319	Unexposed Frames	-	-	-	-	-	-	-	
1320	-	North Galactic Pole	6 Feb.1971	1011	10	$12^h\ 30^m$	$+29^\circ$	$13^h\ 35^m$	$+40^\circ$	
1321	-	" " "	" " "	"	20	$12^h\ 50^m$	$+30^\circ$	$13^h\ 35^m$	$+41^\circ$	
1322	-	" " "	" " "	"	5	$12^h\ 45^m$	$+30^\circ$	$13^h\ 35^m$	$+41^\circ$	
1323	1470	Protect Frames	" " "	-	-	-	-	-	-	
1471	-	Lunar Libration	" " "	1031	60	$13^h\ 50^m$	-17°	$14^h\ 50^m$	-5°	
1472	-	" "	" " "	1032	1	$13^h\ 40^m$	-16°	$14^h\ 45^m$	-5°	
1473	-	" "	" " "	"	20	$14^h\ 55^m$	-17°	$15^h\ 00^m$	-3°	
1474	-	" "	" " "	1033	20	$14^h\ 55^m$	-17°	$15^h\ 00^m$	-3°	
1475	-	" "	" " "	"	5	$14^h\ 55^m$	-17°	$15^h\ 00^m$	-3°	
1476	1563	Protect Frames	" " "	-	-	-	-	-	-	
1564	1568	Ninth Mag Removal	" " "	-	-	-	-	-	-	
1569	1614	Protect Frames	" " "	-	-	-	-	-	-	
1615	-	Earth Darkside	9 Feb.1971	0251	60	-	-	-	-	
1616	-	" "	" " "	0252	20	-	-	-	-	
1617	-	" "	" " "	"	5	-	-	-	-	
1618	1663	Protect Frames	" " "	-	-	-	-	-	-	
1664	1669	Tenth Mag Removal	" " "	-	-	-	-	-	-	
1670	1675	Protect Frames	" " "	-	-	-	-	-	-	
1676	1677	Splice	-	-	-	-	-	-	-	
1678	1700	Protect Frames	9 Feb.1971	-	-	-	-	-	-	
1701	1705	Eleventh Mag Removal	" " "	-	-	-	-	-	-	
1706	1814	Protect Frames	" " "	-	-	-	-	-	-	
1815	-	1st Postflight CAL	17 Feb.1971	1100	5	-	-	-	-	
1816	-	2nd Postflight CAL	" " "	"	20	-	-	-	-	
1817	-	3rd Postflight CAL	" " "	1101	60	-	-	-	-	
1818	1864	Protect Frames	" " "	-	-	-	-	-	-	Orig. Removed for S-178, 3/12/71
1865	1867	" "	" " "	-	-	-	-	-	-	
1868	-	4th Postflight CAL	" " "	1102	5	-	-	-	-	" " " " "
1869	-	5th Postflight CAL	" " "	"	20	-	-	-	-	" " " " "

NASA Magazine No AS 14 Magazine Flight Designator J

Film Type 2485 Film Size 16 mm

Quick Look Begin Fr No	Quick Look End Fr No	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
1870	-	6th Postflight CAL	17 Feb.1971	1103	60	-	-	-	-	Orig. Removed for S-178,3/12/71
1871	1872	Protect Frames	" " "	-	-	-	-	-	-	" " " " "
1874	2174	Unused "	-	-	-	-	-	-	-	" " " " "

APPENDIX B

APOLLO 15 LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY

Apollo 15 photographic data for these studies were recorded on Eastman Kodak type 2485, high-speed, black-and-white film in two different formats--35mm using emulsion number 101-1, and 70mm using emulsion number 33-1. A Nikon camera with 55mm, f/1.2 lens produced the 35mm images and a Hasselblad electric camera with 80mm, f/2.8 lens produced the 70mm images. A Hasselblad photographic series of a lunar eclipse used Eastman Kodak SO-368 color exterior film in 70mm format, and eight of the twenty photographs in this series used the 250mm, f/5.6 lens. All lenses were set at maximum aperture and infinity focus. The Nikon camera and lens provide a field-of-view of 35.5° by 24.0° with a 42.9° diagonal. The Hasselblad with the 80mm lens provides a field-of-view 36.7° square with a 51.8° diagonal, and with the 250mm lens this changes to 11.7° square with a 16.6° diagonal. Calibration of the type 2485 film in both formats was performed on the High Altitude Observatory's Sensitometer Box No. 1 which provides a solar-referenced, color-corrected illumination of a neutral density step-wedge at f/13.7.

In the tables which follow, all times are given to the nearest minute. The centers of frames (Cntr Frm Loc) and corners of frames (Crnr Frm Loc) are given when stellar patterns are sufficiently bright for comparison to star charts, or when weak images may be reliably compared to data in adjacent or similar frames. Protect frames refer to individual frames taken at fast shutter speeds to remove data frames from the imaging position in the event of light leaks that could fog data or prefog frames that are to be used for data.

The low brightness, astronomical photographs on Apollo 15 are presented in the order given below with only those portions of 70mm magazines Q and R presented that were conducted under these studies. This also includes exposures for Experiment S-210/212, Solar Corona Photography.

Flight Mag Desig	NASA Mag Desig	Film Size	Film Type	Starts on Page
T	-101-	35mm	2485	B-2
U	-100-	35mm	2485	B-4
V	-102-	35mm	2485	B-6
W	-	35mm	2485	B-8
Q	-96-	70mm	SO-368	B-10
R	-98-	70mm	2485	B-11

NASA Magazine No AS15-101- Magazine Flight Designator T

Film Type Eastman Kodak 2485 Film Size 35mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
1	-	Film Loading	-	-	-	-	-	-	-	
2	13563	Film Loading Advance Frame	-	-	-	-	-	-	-	
3	13564	Film Loading Advance Frame	-	-	-	-	-	-	-	
4	13565	Protect Frame	-	-	-	-	-	-	-	
5	13566	Lunar Libration Region, L4	31 Jul 71	1337	240	$23^h 15^m$	-3^o	$0^h 30^m$	-12^o	
6	13567	" " " "	"	1342	90	$23^h 10^m$	-2^o	$0^h 30^m$	-12^o	
7	13568	" " " "	"	1344	90	$23^h 05^m$	-2^o	$0^h 25^m$	-12^o	
8	13569	" " " "	"	1346	30	$23^h 05^m$	-2^o	$0^h 25^m$	-12^o	
9	13570	Protect Frame	-	-	-	-	-	-	-	
10	13571	" "	-	-	-	-	-	-	-	
11	13572	" "	-	-	-	-	-	-	-	
12	13573	" "	-	-	-	-	-	-	-	
13	13574	" "	-	-	-	-	-	-	-	
14	13575	" "	-	-	-	-	-	-	-	
15	13576	" "	-	-	-	-	-	-	-	
16	13577	" "	-	-	-	-	-	-	-	
17	13578	" "	-	-	-	-	-	-	-	
18	13579	" "	-	-	-	-	-	-	-	
19	13580	Lunar Surface in Sunlight	1 Aug 71	0849	1/125	-	-	-	-	
20	13581	Lunar Surface in Sunlight	"	0849	1/125	-	-	-	-	
21	13582	Lunar Surface Terminator	"	0850	1/125	-	-	-	-	
22	13583	Lunar Surface in Earthshine	"	0850	1/125	-	-	-	-	
23	13584	" " " "	"	0851	1/15	-	-	-	-	
24	13585	" " " "	"	0851	1/15	-	-	-	-	
25	13586	" " " "	"	0852	1/15	-	-	-	-	
26	13587	" " " "	"	0852	1/15	-	-	-	-	
27	13588	" " " "	"	0853	1/8	-	-	-	-	
28	13589	" " " "	"	0853	1/8	-	-	-	-	
29	13590	" " " "	"	0854	1/8	-	-	-	-	Crater Aristarchus
30	13591	" " " "	"	0854	1/8	-	-	-	-	" "
31	13592	" " " "	"	0855	1/8	-	-	-	-	" "
32	13593	" " " "	"	0855	1/8	-	-	-	-	" "
33	13594	" " " "	"	0856	1/8	-	-	-	-	
34	13595	" " " "	"	0856	1/8	-	-	-	-	
35	13596	" " " "	"	0857	1/8	-	-	-	-	

NASA Magazine No AS15-101-   Magazine Flight Designator T

Film Type Eastman Kodak 2485   Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure		Exp. Time	Cntr Frm Loc		Crnr Frm Loc		Remarks
			Date	GMT	(sec)	Rt Asc	Dec	Rt Asc	Dec	
36	13597	Lunar Surface in Earthshine	1 Aug 71	0857	1/8	-	-	-	-	
37	13598	" " " "	"	0858	1/8	-	-	-	-	
38	13599	Protect Frame	-	-	-	-	-	-	-	
39	13600	Lunar Surface Terminator	1 Aug 71	0900	1/125	-	-	-	-	Postflight Cal. 1/8 sec exp.
40	13601	Lunar Surface in Sunlight	"	0900	1/125	-	-	-	-	" " " " "
41	-	Postflight Calibration Frm	12 Aug 71	-	1/15	-	-	-	-	
42	-	" " "	"	-	1/15	-	-	-	-	
43	-	" " "	"	-	1/125	-	-	-	-	
44	-	" " "	"	-	1/125	-	-	-	-	
45	-	Unused Frame	-	-	-	-	-	-	-	
46	-	" "	-	-	-	-	-	-	-	
47	-	" "	-	-	-	-	-	-	-	
48	-	" "	-	-	-	-	-	-	-	
49	-	Preflight Calibration Frm	18 Jul 71	-	1/8	-	-	-	-	
50	-	" " "	"	-	1/15	-	-	-	-	
51	-	" " "	"	-	1/125	-	-	-	-	
52	-	" " "	"	-	1/8	-	-	-	-	
53	-	" " "	"	-	1/15	-	-	-	-	
54	-	" " "	"	-	1/125	-	-	-	-	

NASA Magazine No AS15-100-　　　Magazine Flight Designator U

Film Type Eastman Kodak 2485　　　Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
1	13507	Protect Frame	-	-	-	-	-	-	-	
2	13508	Delphinus/Milky Way	1 Aug 71	1118	60	$21^h\ 00^m$	$+17^\circ$	$22^h\ 25^m$	$+11^\circ$	Erroneously pointed Gegenschein
3	13509	" " "	"	1119	180	$21^h\ 00^m$	$+17^\circ$	$22^h\ 25^m$	$+11^\circ$	" " "
4	13510	" " "	"	1122	180	$21^h\ 00^m$	$+17^\circ$	$22^h\ 00^m$	$+17^\circ$	" " "
5	13511	Protect Frame	-	-	-	-	-	-	-	
6	13512	" "	-	-	-	-	-	-	-	
7	13513	Zodiacal Light, 75° E. Ecl	1 Aug 71	1334	120	$14^h\ 05^m$	-36°	$14^h\ 25^m$	-16°	
8	13514	" " " " "	"	1336	30	$13^h\ 50^m$	-35°	$14^h\ 30^m$	-20°	
9	13515	" " 65° " "	"	1337	120	$13^h\ 35^m$	-32°	$13^h\ 50^m$	-16°	
10	13516	" " " " "	"	1339	30	$13^h\ 25^m$	-32°	$13^h\ 50^m$	-13°	
11	13517	" " 55° " "	"	1341	90	$12^h\ 55^m$	-29°	$13^h\ 25^m$	-10°	
12	13518	" " " " "	"	1342	30	$12^h\ 50^m$	-28°	$13^h\ 25^m$	-12°	
13	13519	" " " " "	"	1343	10	$12^h\ 45^m$	-27°	$13^h\ 10^m$	-10°	
14	13520	" " 45° " "	"	1344	90	$12^h\ 30^m$	-25°	$13^h\ 05^m$	$-\ 7^\circ$	
15	13521	" " " " "	"	1345	30	$12^h\ 15^m$	-24°	$12^h\ 45^m$	$-\ 5^\circ$	
16	13522	" " " " "	"	1346	10	$12^h\ 10^m$	-23°	$12^h\ 45^m$	$-\ 5^\circ$	
17	13523	Protect Frame	-	-	-	-	-	-	-	
18	13524	" "	-	-	-	-	-	-	-	
19	13525	Zodiacal Light, 35°E.Elong.	1 Aug 71	1347	60	$12^h\ 00^m$	-14°	$12^h\ 30^m$	$-\ 2^\circ$	
20	13526	" " " " "	"	1348	20	$11^h\ 55^m$	-13°	$12^h\ 20^m$	$+\ 5^\circ$	
21	13527	" " " " "	"	1349	8	$11^h\ 55^m$	-13°	$12^h\ 15^m$	$+\ 8^\circ$	
22	13528	" " 25°" "	"	1351	60	$11^h\ 35^m$	0°	$12^h\ 20^m$	$+14^\circ$	
23	13529	" " " " "	"	1352	20	$11^h\ 30^m$	$+\ 7^\circ$	$12^h\ 15^m$	$+20^\circ$	
24	13530	" " " " "	"	1353	8	$11^h\ 25^m$	$+\ 7^\circ$	$12^h\ 10^m$	$+21^\circ$	
25	13531	" " 15°" "	"	1354	30	$11^h\ 10^m$	$+11^\circ$	$11^h\ 45^m$	$+16^\circ$	
26	13532	" " " " "	"	1355	10	$11^h\ 10^m$	$+13^\circ$	$11^h\ 15^m$	$+19^\circ$	
27	13533	" " " " "	"	1355	4	$11^h\ 05^m$	$+12^\circ$	$11^h\ 15^m$	$+19^\circ$	
28	13534	" " 3.0° " "	"	1357	1/8	$10^h\ 50^m$	$+15^\circ$	$11^h\ 05^m$	$+23^\circ$	
29	13535	" " 2.3° " "	"	1357	1/15	$10^h\ 50^m$	$+15^\circ$	$11^h\ 05^m$	$+23^\circ$	
30	13536	" " 1.5° " "	"	1358	1/30	$10^h\ 45^m$	$+16^\circ$	$11^h\ 00^m$	$+24^\circ$	
31	13537	" " 0.8° " "	"	1358	1/60	$10^h\ 45^m$	$+16^\circ$	$11^h\ 00^m$	$+24^\circ$	
32	13538	Protect Frame	-	-	-	-	-	-	-	
33	13539	" "	-	-	-	-	-	-	-	
34	13540	Delphinus/Milky Way	2 Aug 71	0901	60	$20^h\ 20^m$	$+19^\circ$	$19^h\ 00^m$	$+12^\circ$	
35	13541	" " "	"	0902	180	$20^h\ 20^m$	$+19^\circ$	$19^h\ 00^m$	$+12^\circ$	

NASA Magazine No AS15-100- Magazine Flight Designator U

Film Type Eastman Kodak 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
36	13542	Protect Frame	-	-	-	-	-	-	-	
37	13543	" "	-	-	-	-	-	-	-	
38	13544	Delphinus/Milky Way	2 Aug 71	0909	60	$20^h\ 50^m$	$+16^o$	$19^h\ 40^m$	$+ 9^o$	
39	13545	" " "	"	0910	180	$21^h\ 00^m$	$+16^o$	$19^h\ 40^m$	$+ 8^o$	
40	13546	Protect Frame	-	-	-	-	-	-	-	
41	13547	" "	-	-	-	-	-	-	-	
42	13548	Delphinus/Milky Way	2 Aug 71	0917	60	$21^h\ 30^m$	$+12^o$	$20^h\ 20^m$	$+ 7^o$	
43	13549	" " "	"	0918	180	$21^h\ 35^m$	$+13^o$	$20^h\ 20^m$	$+ 7^o$	
44	13550	Protect Frame	-	-	-	-	-	-	-	
45	13551	Unused Frame	-	-	-	-	-	-	-	
46	13552	" "	-	-	-	-	-	-	-	
47	13553	" "	-	-	-	-	-	-	-	
48	13554	" "	-	-	-	-	-	-	-	
49	13555	" "	-	-	-	-	-	-	-	
50	13556	" "	-	-	-	-	-	-	-	

NASA Magazine No AS15-102- Magazine Flight Designator V

Film Type Eastman Kodak 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
1	13602	Film Loading Advance Frame	-	-	-	-	-	-	-	
2	13603	" " " "	-	-	-	-	-	--	-	
3	13604	Protect Frame	-	-	-	-	-	-	-	
4	13605	Protect Frame	-	-	-	-	-	-	-	
5	13606	Delphinus/Milky Way	3 Aug 71	1231	60	$20^h\ 50^m$	$+17^\circ$	$19^h\ 30^m$	$+12^\circ$	Erroneously Pointed Gegenschein
6	13607	" " "	"	1232	180	$20^h\ 50^m$	$+17^\circ$	$19^h\ 30^m$	$+12^\circ$	" " "
7	13608	Protect Frame	-	-	-	-	-	-	-	
8	13609	" "	-	-	-	-	-	-	-	
9	13610	Delphinus/Milky Way	3 Aug 71	1248	30	$21^h\ 30^m$	$+12^\circ$	$20^h\ 15^m$	$+11^\circ$	Erroneously Pointed Gegenschein
10	13611	" " "	"	1249	60	$21^h\ 30^m$	$+12^\circ$	$20^h\ 15^m$	$+11^\circ$	" " "
11	13612	" " "	"	1250	180	$21^h\ 30^m$	$+11^\circ$	$20^h\ 10^m$	$+9^\circ$	" " "
12	13613	Protect Frame	-	-	-	-	-	-	-	
13	13614	Lunar Eclipse Entry	6 Aug 71	1338	< 1	$21^h\ 40^m$	-4°	$23^h\ 25^m$	-10°	
14	13615	" " "	"	1338	2	$21^h\ 40^m$	-3°	$23^h\ 25^m$	-6°	
15	13616	" " "	"	1339	4	$21^h\ 40^m$	-3°	$23^h\ 25^m$	-6°	
16	13617	" " "	"	1339	~ 1	$21^h\ 40^m$	-3°	$23^h\ 25^m$	-6°	
17	13618	" " "	"	1340	8	$21^h\ 40^m$	-3°	$23^h\ 25^m$	-6°	
18	13619	" " "	"	1341	15	$21^h\ 40^m$	-3°	$23^h\ 25^m$	-6°	
19	13620	" " "	"	1342	30	$21^h\ 40^m$	-3°	$23^h\ 25^m$	-6°	
20	13621	" " "	"	1343	60	$21^h\ 40^m$	-3°	$23^h\ 30^m$	-6°	
21	13622	Protect Frame	-	-	-	-	-	-	-	
22	13623	" "	-	-	-	-	-	-	-	
23	13624	Lunar Eclipse Exit	6 Aug 71	1525	60	$22^h\ 30^m$	$+2^\circ$	$21^h\ 20^m$	$+18^\circ$	
24	13625	" " "	"	1526	30	$22^h\ 30^m$	$+2^\circ$	$21^h\ 20^m$	$+18^\circ$	
25	13626	" " "	"	1527	15	$22^h\ 30^m$	$+2^\circ$	$21^h\ 20^m$	$+18^\circ$	
26	13627	" " "	"	1528	8	$22^h\ 30^m$	$+2^\circ$	$21^h\ 20^m$	$+18^\circ$	
27	13628	" " "	"	1529	~ 1	$22^h\ 30^m$	$+2^\circ$	$21^h\ 20^m$	$+18^\circ$	
28	13629	" " "	"	1529	4	$22^h\ 30^m$	$+3^\circ$	$21^h\ 20^m$	$+18^\circ$	
29	13630	" " "	"	1530	2	$22^h\ 30^m$	$+5^\circ$	$21^h\ 20^m$	$+18^\circ$	
30	13631	Protect Frame	-	-	-	-	-	-	-	
31	13632	Unused Frame	-	-	-	-	-	-	-	
32	13633	Postflight Calibration Frm	12 Aug 71	-	15	-	-	-	-	3.0 ND Filter
33	13634	" " "	"	-	10	-	-	-	-	" " "
34	13635	" " "	"	-	10	-	-	-	-	" " "
35	13636	" " "	"	-	9	-	-	-	-	" " "

NASA Magazine No AS15-102- Magazine Flight Designator V

Film Type Eastman Kodak 2425 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
36	13637	Postflight Calibration Frm	12 Aug 71	-	8	-	-	-	-	3.0 ND Filter
37	13638	" " "	"	-	4	-	-	-	-	" " "
38	13639	" " "	"	-	4	-	-	-	-	" " "
39	13640	" " "	"	-	2	-	-	-	-	" " "
40	13641	" " "	"	-	2	-	-	-	-	" " "
41	13642	" " "	"	-	1/8	-	-	-	-	" " "
42	13643	" " "	"	-	1/8	-	-	-	-	" " "
43	13644	" " "	"	-	1/15	-	-	-	-	" " "
44	13645	" " "	"	-	1/15	-	-	-	-	" " "
45	13646	" " "	"	-	1/30	-	-	-	-	" " "
46	13647	" " "	"	-	1/30	-	-	-	-	" " "
47	13648	" " "	"	-	1/60	-	-	-	-	" " "
48	13649	" " "	"	-	1/60	-	-	-	-	" " "
49	13650	Unused Frame	-	-	-	-	-	-	-	
50	13651	MSC Photo Lab Calibrations	18 Jul 71/ 12 Aug 71	-	1/100	-	-	-	-	

NASA Magazine No NONE Magazine Flight Designator W

Film Type Eastman Kodak 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
1		Preflight Calibration Frm.	18 Jul 71	-	240	-	-	-	-	3.0 ND Filter
2		" " "	"	-	240	-	-	-	-	" " "
3		" " "	"	-	180	-	-	-	-	" " "
4		" " "	"	-	180	-	-	-	-	" " "
5		" " "	"	-	120	-	-	-	-	" " "
6		" " "	"	-	120	-	-	-	-	" " "
7		" " "	"	-	90	-	-	-	-	" " "
8		" " "	"	-	90	-	-	-	-	" " "
9		" " "	"	-	60	-	-	-	-	" " "
10		" " "	"	-	60	-	-	-	-	" " "
11		" " "	"	-	30	-	-	-	-	" " "
12		" " "	"	-	30	-	-	-	-	" " "
13		" " "	"	-	2	-	-	-	-	" " "
14		" " "	"	-	20	-	-	-	-	" " "
15		" " "	"	-	15	-	-	-	-	" " "
16		" " "	"	-	15	-	-	-	-	" " "
17		" " "	"	-	10	-	-	-	-	" " "
18		" " "	"	-	10	-	-	-	-	" " "
19		" " "	"	-	8	-	-	-	-	" " "
20		" " "	"	-	8	-	-	-	-	" " "
21		" " "	"	-	4	-	-	-	-	" " "
22		" " "	"	-	4	-	-	-	-	" " "
23		" " "	"	-	2	-	-	-	-	" " "
24		" " "	"	-	2	-	-	-	-	" " "
25		" " "	"	-	1/8	-	-	-	-	" " "
26		" " "	"	-	1/8	-	-	-	-	" " "
27		" " "	"	-	1/15	-	-	-	-	" " "
28		" " "	"	-	1/15	-	-	-	-	" " "
29		" " "	"	-	1/30	-	-	-	-	" " "
30		" " "	"	-	1/30	-	-	-	-	" " "
31		" " "	"	-	1/60	-	-	-	-	" " "
32		" " "	"	-	1/60	-	-	-	-	
33		Protect Frame	-	-	-	-	-	-	-	
34		Postflt. Calibration Frame	12 Aug 71	-	240	-	-	-	-	3.0 ND Filter
35		" " "	"	-	240	-	-	-	-	" " "

NASA Magazine No NONE Magazine Flight Designator W

Film Type Eastman Kodak 2485 Film Size 35mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure		Exp. Time (sec)	Cntr Frm Loc		Crnr Frm Loc		Remarks
			Date	GMT		Rt Asc	Dec	Rt Asc	Dec	
36		Postflt. Calibration Frame	12 Aug 71	-	180	-	-	-	-	3.0 ND Filter
37		" " "	"	-	180	-	-	-	-	" " "
38		" " "	"	-	2.5	-	-	-	-	" " "
39		" " "	"	-	120	-	-	-	-	" " "
40		" " "	"	-	90	-	-	-	-	" " "
41		" " "	"	-	90	-	-	-	-	" " "
42		" " "	"	-	60	-	-	-	-	" " "
43		" " "	"	-	60	-	-	-	-	" " "
44		" " "	"	-	30	-	-	-	-	" " "
45		" " "	"	-	30	-	-	-	-	" " "
46		" " "	"	-	20	-	-	-	-	" " "
47		" " "	"	-	20	-	-	-	-	" " "
48		" " "	"	-	15	-	-	-	-	" " "

NASA Magazine No AS15-96- Magazine Flight Designator Q(partial)

Film Type Eastman Kodak SO-368 Film Size 70 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
1	13105	Protect Frame	-	-	1/500	-	-	-	-	
2	13106	Lunar Eclipse	6 Aug 71	1324	1	$23^h\ 40^m$	$+6^\circ$	-	-	250 mm Lens
3	13107	" "	"	1324	1	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
4	13108	" "	"	1327	2	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
5	13109	" "	"	1327	2	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
6	13110	" "	"	1327	1	$23^h\ 40^m$	$+6^\circ$	-	-	80 mm Lens
7	13111	" "	"	1330	1	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
8	13112	" "	"	1330	2	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
9	13113	" "	"	1333	2	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
10	13114	" "	"	1333	10	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
11	13115	" "	"	1336	10	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
12	13116	" "	"	1336	120	$23^h\ 40^m$	$+6^\circ$	-	-	" " "
13	13117	Protect Frame	-	-	1/500	-	-	-	-	
14	13118	Lunar Eclipse	6 Aug 71	1528	120	$23^h\ 45^m$	$+7^\circ$	-	-	" " "
15	13119	" "	"	1532	10	$23^h\ 45^m$	$+7^\circ$	-	-	" " "
16	13120	" "	"	1535	2	$23^h\ 45^m$	$+7^\circ$	-	-	" " "
17	13121	" "	"	1535	2	$23^h\ 45^m$	$+7^\circ$	-	-	" " "
18	13122	" "	"	1538	1	$23^h\ 45^m$	$+7^\circ$	-	-	" " "
19	13123	" "	"	1541	2	$23^h\ 45^m$	$+7^\circ$	-	-	250 mm Lens
20	13124	" "	"	1541	2	$23^h\ 45^m$	$+7^\circ$	-	-	" " "
21	13125	" "	"	1544	1	$23^h\ 45^m$	$+7^\circ$	-	-	" " "
22	13126	" "	"	1544	1	$23^h\ 45^m$	$+7^\circ$	-	-	" " "
23	13127	Protect Frame	-	-	1/500	-	-	-	-	

NASA Magazine No AS15-98- Magazine Flight Designator R (Partial)

Film Type Eastman Kodak 2485 Film Size 70 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
-	-	Preflight Calibration Frm	18 Jul 71	-	1/125	-	-	-	-	
-	-	" " "	"	-	1/60	-	-	-	-	
-	-	" " "	"	-	1/30	-	-	-	-	
-	-	" " "	"	-	1/15	-	-	-	-	
-	-	" " "	"	-	1/8	-	-	-	-	
-	-	" " "	"	-	1/4	-	-	-	-	
-	-	" " "	"	-	1	-	-	-	-	
1	13309	Protect Frame	-	-	1/500	-	-	-	-	
2	13310	Solar Corona Sunrise	31 Jul 71	1159	1	-	-	-	-	GET 123:23:40, SR -70 sec.
3	13311	" " "	"	1159	~10	$9^h\ 20^m$	$+13^o$	$11^h\ 20^m$	$+18^o$	GET 123:23:50, SR -60 sec.
4	13312	" " "	"	1159	1/8	-	-	-	-	GET 123:24:00, SR -50 sec.
5	13313	" " "	"	1159	1/15	-	-	-	-	GET 123:24:10, SR -40 sec.
6	13314	" " "	"	1159	1/30	-	-	-	-	GET 123:24:20, SR -30 sec.
7	13315	" " "	"	1159	1/60	-	-	-	-	GET 123:24:30, SR -20 sec.
8	13316	" " "	"	1200	1/125	-	-	-	-	GET 123:24:40, SR -10 sec.
9	13317	Protect Frame	"	1200	1/500	-	-	-	-	GET 123:24:50, Sunrise
10	13318	Solar Corona Sunset	"	1311	1/125	-	-	-	-	GET 124:37:32, SS +10 sec.
11	13319	" " "	"	1311	1/60	-	-	-	-	GET 124:37:42, SS +20 sec
12	13320	" " "	"	1311	1/30	-	-	-	-	GET 124:37:52, SS +30 sec.
13	13321	" " "	"	1311	1/15	-	-	-	-	GET 124:38:02, SS +40 sec.
14	13322	" " "	"	1311	1/8	-	-	-	-	GET 124:38:12, SS +50 sec.
15	13323	" " "	"	1311	1/4	-	-	-	-	GET 124:38:22, SS +60 sec.
16	13324	" " "	"	1312	1	-	-	-	-	GET 124:38:32, SS +70 sec.
17	13325	" " "	"	1312	~10	$7^h\ 55^m$	$+38^o$	$6^h\ 20^m$	$+30^o$	Earthshine on Lunar Surface
18	13377	Solar Corona Sunrise	4 Aug 71	0845	1	-	-	-	-	GET 216:10:45, SR -70 sec.
19	13378	" " "	"	0845	1/4	-	-	-	-	GET 216:10:55, SR -60 sec.
20	13379	" " "	"	0845	1/8	-	-	-	-	GET 216:11:05, SR -50 sec.
21	13380	" " "	"	0845	1/15	-	-	-	-	GET 216:11:15, SR -40 sec.
22	13381	" " "	"	0845	1/30	-	-	-	-	GET 216:11:25, SR -30 sec.
23	13382	" " "	"	0845	1/60	-	-	-	-	GET 216:11:35, SR -20 sec.
24	13383	" " "	"	0846	1/125	-	-	-	-	GET 216:11:45, SR -10 sec.
25	13384	" " "	"	0846	1/250	-	-	-	-	GET 216:11:50, SR - 5 sec.
26	13385	Protect Frame	"	0846	1/500	-	-	-	-	GET 216:11:55, Sunrise
27	13398	Solar Corona Calibration	5 Aug 71	0739	1/125	-	-	-	-	Lunar Disc

NASA Magazine No AS15-98 Magazine Flight Designator R (Partial)

Film Type Eastman Kodak 2485 Film Size 70 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
28	13399	Solar Corona Calibration	5 Aug 71	0739	1/60	-	-	-	-	Lunar Disc
29	13400	" " "	"	0739	1/30	-	-	-	-	Lunar Disc
30	13401	" " "	"	0739	1/500	-	-	-	-	Lunar Disc

APPENDIX C

APOLLO 16 LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY

Apollo 16 photographic data for these studies were recorded on Eastman Kodak type 2485, high-speed, black-and-white film in three different formats -- 16mm, 35mm and 70mm, all using emulsion number 107-2. A DAC with 18mm, f/0.95 (T/1.0) lens, a Nikon camera with 55mm, f/1.2 lens, and a Hasselblad electric camera with 80mm, f/2.8 lens were used in the photography. These camera and lens combinations provide formats and fields-of-view, respectively, of 16mm and 32.6° by 23.4° with 39.2° diagonal, of 35mm and 35.5° by 24.0° with a 42.9° diagonal and of 70mm and 36.7° square with a 51.8° diagonal. The DAC and Hasselblad low brightness exposures were obtained for Experiment S-210/212, Solar Corona Photography, which had achieved an independent status on Apollo 16; therefore, it is not included in these tables. Experiment S-178, Gegenschein/Moulton Region Photography used the 35mm format and is included in Magazine ZZ. Films for all three formats were calibrated on the High Altitude Observatory's Sensitometer Box No. 2 which provides a solar-referenced, color-corrected illuminations of a neutral density step-wedge at f/13.7.

Red, blue and polaroid filters were carried on this mission. These front-end filters were used ahead of the 55mm lens, and the polaroid filter was rotated between two end-stops 90° apart so that plane polarization properties of the white light could be analyzed. The window cutoff and blue filter characteristics established a bandpass of 420 to 510 nanometers; the red filter and emulsion cutoff characteristics established a bandpass of 610 to 700 nanometers. Color filters were specifically included to photograph the Gum Nebula. The polaroid filter was included for white light analysis of zodiacal light. Unless otherwise specified in the Subject column, all exposures listed recorded the scene in white, unpolarized light.

In the tables which follow, all times are given to the nearest minute. The center of frames (Cntr Frm Loc) and corners of frames (Crnr Frm Loc) are given when stellar patterns are sufficiently bright for comparison to star charts, or when weak images may be reliably compared to data in adjacent or similar frames. Protect frames refer to individual frames taken at fast shutter speeds to remove data frames from the imaging position in the event of light leaks that could fog data or prefog frames that are to be used for data.

The low brightness, astronomical photographs on 35mm, type 2485 film from Apollo 16 are presented in the order given below. In addition, listings of backup Magazines W and Y containing preflight calibrations are also given. These emulsions, which remained on the ground, did not receive the hard radiation fogging experienced by the flight film in the Command Module.

NASA Magazine No AS16-128 Magazine Flight Designator MAG W (Labeled Y on film)

Film Type 2485 Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
1		Calibration, ND 3 Filter	10 Apr 72		300					
2		" " " "	" " "		"					
3		" " " "	" " "		180					
4		" " " "	" " "		"					
5		" " " "	" " "		100					
6		" " " "	" " "		"					
7		" " " "	" " "		90					
8		" " " "	" " "		1(?)					
9		" " " "	" " "		90					
10		" " " "	" " "		60					
11		" " " "	" " "		"					
12		" " " "	" " "		30					
13		" " " "	" " "		"					
14		" " " "	" " "		20					
15		" " " "	" " "		"					
16		Calibration No. Filter	" " "		20					
17		" " "	" " "		"					
18		" " "	" " "		10					
19		" " "	" " "		"					
20		" " "	" " "		5					
21		" " "	" " "		"					
22		" " "	" " "		3					
23		" " "	" " "		"					
24		" " "	" " "		1					
25		" " "	" " "		"					
26		" " "	" " "		½					
27		" " "	" " "		"					
28		" " "	" " "		¼					
29		" " "	" " "		"					
30		" " "	" " "		1/8					
31		" " "	" " "		"					
32		" " "	" " "		1/15					
33		" " "	" " "		"					
34		" " "	" " "		1/30					
35		" " "	" " "		"					
36		" " "	" " "		1/60					

NASA Magazine No AS16-128   Magazine Flight Designator MAG W (Labeled Y on Film)

Film Type 2485   Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
37		Calibration No. Filter	10 Apr 72		1/60					
38		" " "	" " "		1/1000					
39		" " "	" " "		"					
	20027	Unused Frame								
	20028	" "								
	20029	" "								
	20030	" "								
	20031	" "								
	20032	" "								

NASA Magazine No AS16-129 Magazine Flight Designator X

Film Type 2485 Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
1	20079	Protect Frame								
2	20078	" "								
3	20077	Skylab Contamination			1/8					Attitude #1
4	20076	" "			1					" "
5	20075	" "			10					" "
6	20074	" "			100					" "
7	20073	" "			1/8					" "
8	20072	" "			1					" "
9	20071	" "			10					" "
10	20070	" "			100					" "
11	20069	" "			1/8					Attitude #2
12	20068	" "			1					" "
13	20067	" "			10					" "
14	20066	" "			100					" " Moon Shining in
15	20065	" "			1/8					" ", Moon Shining in
16	20064	" "			1					" " " " "
17	20063	" "			10					" " " " "
18	20062	" "			100					" " " " "
19	20061	Protect Frame								
	20060	Unused Frame								
	20059	" "								
	20058	" "								
	20057	" "								
	20056	" "								
	20055	" "								
	20054	" "								
	20053	" "								
	20052	" "								
	20051	" "								
	20050	" "								
	20049	" "								
	20048	" "								
	20047	" "								
	20046	" "								
	20045	" "								
	20044									

NASA Magazine No AS16-129 Magazine Flight Designator X

Film Type 2485 Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure		Exp. Time (sec)	Cntr Frm Loc		Crnr Frm Loc		Remarks
			Date	GMT		Rt Asc	Dec	Rt Asc	Dec	
	20043	Unused Frame								
	20042	" "								
	20041	" "								
	20040	" "								
	20039	" "								
	20038	" "								
	20037	" "								
	20036	" "								
	20035	" "								
	20034	" "								
	20033	" "								

NASA Magazine No AS16-130 Magazine Flight Designator MAG Y (Labeled W on film)

Film Type 2485 Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
	20080	Unused Frame								
	20081	" "								
	20082	" "								
	20083	" "								
	20084	" "								
	20085	" "								
	20086	" "								
	20087	" "								
	20088	" "								
	20089	" "								
	20090	" "								
	20091	" "								
	20092	" "								
	20093	" "								
1		Calibration, Red Filter	10 Apr 72		240					
2		" " "	" " "		"					
3		" " "	" " "		60					
4		" " "	" " "		"					
5		Calibration, Blue Filter	" " "		240					
6		" " "	" " "		"					
7		" " "	" " "		60					
8		" " "	" " "		"					
9		Calibration, Polaroid Filt.	" " "		1/1000					
10		" " "	" " "		1/60					
11		" " "	" " "		1/30					
12		" " "	" " "		1/15					
13		" " "	" " "		1/8					
14		" " "	" " "		¼					
15		" " "	" " "		½					
16		" " "	" " "		1					
17		" " "	" " "		3					
18		" " "	" " "		5					
19		" " "	" " "		10					
20		" " "	" " "		20					
21		" " "	" " "		30					
22		" " "	" " "		60					

NASA Magazine No AS16-130　　　Magazine Flight Designator MAG Y (Labeled W on film)

Film Type 2485　　　Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
23		Calibration, Polaroid Filt.	10 Apr 72		90					
	20094	Unused Frame								
	20095	" "								
	20096	" "								
	20097	" "								
	20098	" "								
	20099	" "								

NASA Magazine No AS16-127 Magazine Flight Designator XX

Film Type 2485 Film Size 35MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
1		Unused Frame								
2	20026	Protect Frame								Light Streak
3	20025	" "								Half Light Streak, Half Dark
4	20024	Gum Nebula,Pt.1,Red Filt.	21 Apr. 72	1847	60	$7^h\ 20^m$	-30°	$6^h\ 10^m$	-15°	
5	20023	" " " " "	" " "	1848	240	$7^h\ 20^m$	-32°	$6^h\ 10^m$	-15°	
6	20022	" " " Blue "	" " "	1856	60	$7^h\ 20^m$	-30°	$6^h\ 20^m$	-17°	
7	20021	" " " " "	" " "	1857	240	$7^h\ 35^m$	-33°	$6^h\ 30^m$	-17°	
8	20020	Protect Frame								
9	20019	Earthshine	21 Apr. 72	2022	1/125	76.0° W	2.0°S	80.0° W	1°NL*	Selenographic coordinates
10	20018	"	" " "	2024	"	69.5° W	1.0°S	73.0° W	0.0°	Surface contrast extremely weak
11	20017	"	" " "	2026	"	-	-	-	-	" " " "
12	20016	"	" " "	2028	"	-	-	-	-	" " " "
13	20015	"	" " "	2030	"	-	-	-	-	" " " "
14	20014	"	" " "	2032	"	-	-	-	-	" " " "
15	20013	Protect Frame								
16	20012	Zodiacal Light	21 Apr. 72	2052	90	$6^h\ 00^m$	45°	$4^h\ 40^m$	35°	
17	20011	" "	" " "	2054	90	$5^h\ 50^m$	44°	$4^h\ 25^m$	35°	
18	20010	" "	" " "	2056	60	$5^h\ 00^m$	44°	$3^h\ 55^m$	32°	
19	20009	" "	" " "	2057	"	$4^h\ 40^m$	42°	$3^h\ 30^m$	29°	
20	20008	" "	" " "	2059	30	$4^h\ 20^m$	39°	$3^h\ 10^m$	29°	
21	20007	" "	" " "	2101	"	$4^h\ 00^m$	41°	$3^h\ 10^m$	29°	Bright Object Venus
22	20006	" "	" " "	2102	20	$3^h\ 50^m$	36°	$3^h\ 00^m$	26°	
23	20005	" "	" " "	2103	"	$3^h\ 30^m$	36°	$3^h\ 40^m$	26°	
24	20004	" "	" " "	2104	10	$3^h\ 30^m$	35°	$2^h\ 05^m$	25°	
25	20003	" "	" " "	2104	01					Star images to weak
26	20002	" "	" " "	2104	10	$3^h\ 30^m$	35°	$2^h\ 05^m$	25°	
27	20001	" "	" " "	2105	05	$3^h\ 30^m$	35°	$2^h\ 05^m$	25°	
28	20000	" "	" " "	2105	"	$3^h\ 25^m$	35°	$2^h\ 00^m$	25°	
29	19999	" "	" " "	2105	03	$3^h\ 20^m$	33°	$1^h\ 50^m$	25°	
30	19998	" "	" " "	2105	"	$3^h\ 20^m$	33°	$1^h\ 50^m$	25°	
31	19997	" "	" " "	2105	01					Star images too weak
32	19996	" "	" " "	2105	"					" " " "
33	19995	" "	" " "	2105	1/8					" " " "
34	19994	" "	" " "	2106	"					" " " "
35	19993	" "	" " "	2106	1/15					" " " "
36	19992	" "	" " "	2106	"					" " " "

NASA Magazine No AS16-127 Magazine Flight Designator XX

Film Type 2485 Film Size 35MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
37	19991	Zodiacal Light	21 Apr. 72	2106	1/30					Star images too weak
38	19990	" "	" " "	2106	"					" " " "
39	19989	" "	" " "	2106	1/60					" " " "
40	19988	" "	" " "	2107	"					" " " "
41	19987	Protect Frame								
--	19986	Unused Frame								
--	19985	" "								
--	19984	" "								
--	19983	" "								
--	19982	" "								
--	19981	" "								
--	19980	" "								

NASA Magazine No NONE

Magazine Flight Designator MAG YY (Postflight Calibration)

Film Type 2485

Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
1		Calibration, ND 3 Filter	2 May 1972		300					309^s Actual
2		" " "	" " "		180					Lost in 2nd light leak
3		" " "	" " "		100					
4		" " "	" " "		90					
5		" " "	" " "		60					Lower wedges lost in 4th light leak
6		" " "	" " "		30					
7		" " "	" " "		20					Lost in 5th light leak
8		" " "	" " "		10					
9		" " "	" " "		5					
10		Calibration, No Filter	" " "		30					
11		" " "	" " "		20					
12		" " "	" " "		10					
13		" " "	" " "		5					
14		" " "	" " "		3					
15		" " "	" " "		1					
16		" " "	" " "		½					
17		" " "	" " "		¼					
18		" " "	" " "		1/8					
19		" " "	" " "		1/15					
20		" " "	" " "		1/30					
21		" " "	" " "		1/60					
22		" " "	" " "		1/1000					
23		Calibration, Red Filter	" " "		240					
24		" " "	" " "		60					
25		Calibration, Red & ND 3 Fil.	" " "		240					
26		" " " " " "	" " "		60					
27		Calibration, Blue Filter	" " "		240					
28		" " "	" " "		60					
29		Calibration, Blue & ND 3 Fil.	" " "		240					
30		" " " " "	" " "		60					
31		Calibration, Polaroid Filt.	" " "		1/1000					
32		" " "	" " "		1/60					
33		" " "	" " "		1/30					
34		" " "	" " "		1/15					
35		" " "	" " "		1/8					
36		" " "	" " "		¼					

NASA Magazine No NONE

Magazine Flight Designator MAG YY

(Post flight Calibrati

Film Type 2485

Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
37		Calibration, Polaroid Filt.	2 May 1972		½					
38		" " "	" " "		1					
39		" " "	" " "		3					
40		" " "	" " "		5					
41		" " "	" " "		10					
42		" " "	" " "		20					
43		" " "	" " "		30					
44		" " "	" " "		60					
45		" " "	" " "		90					
46		Calibration, ND 3 Filter	" " "		90					
47		" " " "	" " "		60					

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
1	19979	Protect Frame								
2	19978	" "								
3	19977	Gegenschein Calibration	22 Apr 72	0043	3	-	-	-	-	Star images too weak
4	19976	" "	" " "	0043	60	$14^h\ 10^m$	-24°	$15^h\ 10^m$	-15°	
5	19975	" "	" " "	0044	180	$14^h\ 10^m$	-26°	$15^h\ 25^m$	-20°	
6	19974	Protect Frame								
7	19973	" "								
8	19972	Galactic Cluster in Virgo	22 Apr 72	1612	300	$12^h\ 20^m$	$+9^\circ$	$11^h\ 00^m$	$+5^\circ$	
9	19971	Gegenschein/Moulton Region	" " "	1617	60	$13^h\ 45^m$	-12°	$12^h\ 20^m$	-08°	
10	19970	" " "	" " "	1619	180	$13^h\ 45^m$	-12°	$12^h\ 20^m$	-08°	
11	19969	" " "	" " "	1623	180	$14^h\ 10^m$	-14°	$13^h\ 00^m$	-11°	
12	19968	" " "	" " "	1627	60	$14^h\ 20^m$	-11°	$13^h\ 00^m$	-12°	
13	19967	" " "	" " "	1629	180	$14^h\ 50^m$	-18°	$16^h\ 10^m$	-12°	
14	19966	" " "	" " "	1632	60	$14^h\ 50^m$	-18°	$16^h\ 25^m$	-15°	
15	19965	Protect Frame								
16	19964	" "								
17	19963	Gum Nebula Pt.2,Red Filt.	24 Apr 72	2142	240	$8^h\ 40^m$	-48°	$10^h\ 20^m$	-39°	
18	19962	" " " " " "	" " "	2146	60	$8^h\ 40^m$	-52°	$10^h\ 20^m$	-40°	
19	19961	" " " " Blue "	" " "	2148	60	$8^h\ 30^m$	-49°	$10^h\ 00^m$	-37°	
20	19960	" " " " " "	" " "	2150	30	$8^h\ 40^m$	-49°	$9^h\ 50^m$	-39°	
21	19959	" " " " " "	" " "	2151	240	$8^h\ 35^m$	-48°	$9^h\ 55^m$	-41°	
22	19958	Protect Frame								
23	19957	Inside cabin H_2O Droplet								
24	19956	" " " "								
25	19955	Protect Frame								
26	19954	Gegenschein/Moulton Region	25 Apr 72	0342	180	$14^h\ 55^m$	-19°	$13^h\ 50^m$	-32°	
27	19953	" " "	" " "	0345	60	$14^h\ 50^m$	-18°	$14^h\ 00^m$	-30°	
28	19952	" " "	" " "	0347	180	$14^h\ 25^m$	-15°	$14^h\ 40^m$	-35°	
29	19951	" " "	" " "	0352	?	$14^h\ 25^m$	-15°	$14^h\ 40^m$	-35°	
30	19950	" " "	" " "	0353	60	$14^h\ 20^m$	-15°	$14^h\ 45^m$	-30°	
31	19949	Galactic Clust.in Centaurus	" " "	0356	300	$13^h\ 10^m$	-39°	$13^h\ 55^m$	-52°	
32	19948	Protect Frame								
	19947	Unused Frame								
	19946	" "								
	19945	" "								
	19944	" "								
	19943	" "								

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
	19942	Unused Frame								
	19941	" "								
	19940	" "								
	19939	" "								
	19938	" "								
	19937	" "								
	19936	" "								
	19935	" "								
	19934	" "								
	19933	" "								

NASA Magazine No NONE   Magazine Flight Designator MAG W (Back Up, Ground)

Film Type 2485   Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Cntr Frm Loc Dec	Crnr Frm Loc Rt Asc	Crnr Frm Loc Dec	Remarks
1		Calibration, ND 3 Filter	10 Apr 72		300					
2		" " " "	" " "		"					
3		" " " "	" " "		180					
4		" " " "	" " "		"					
5		" " " "	" " "		100					
6		" " " "	" " "		"					
7		" " " "	" " "		90					
8		" " " "	" " "		"					
9		" " " "	" " "		60					
10		" " " "	" " "		"					
11		" " " "	" " "		30					
12		" " " "	" " "		"					
13		" " " "	" " "		20					
14		" " " "	" " "		"					
15		Calibration, NO Filter	" " "		20					
16		" " "	" " "		"					
17		" " "	" " "		10					
18		" " "	" " "		"					
19		" " "	" " "		5					
20		" " "	" " "		"					
21		" " "	" " "		3					
22		" " "	" " "		"					
23		" " "	" " "		1					
24		" " "	" " "		"					
25		" " "	" " "		½					
26		" " "	" " "		"					
27		" " "	" " "		¼					
28		" " "	" " "		"					
29		" " "	" " "		1/8					
30		" " "	" " "		"					
31		" " "	" " "		1/15					
32		" " "	" " "		"					
33		" " "	" " "		1/30					
34		" " "	" " "		"					
35		" " "	" " "		1/60					
36		" " "	" " "		"					

NASA Magazine No NONE Magazine Flight Designator MAG W (Back Up, Ground)

Film Type 2485 Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure		Exp. Time (sec)	Cntr Frm Loc		Crnr Frm Loc		Remarks
			Date	GMT		Rt Asc	Dec	Rt Asc	Dec	
37		Calibration, NO Filter	10 Apr 72		1/1000					
38		" " "	" " "		"					

(Back up, Ground)

NASA Magazine No NONE   Magazine Flight Designator MAG Y

Film Type 2485   Film Size 35 MM

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	Cntr Frm Loc Rt Asc	Dec	Crnr Frm Loc Rt Asc	Dec	Remarks
1		Calibration, Red Filter	10 Apr 72		240					
2		" " "	" " "		"					
3		" " "	" " "		60					
4		" " "	" " "		"					
5		Calibration, Blue Filter	" " "		240					
6		" " "	" " "		"					
7		" " "	" " "		60					
8		" " "	" " "		"					
9		Calibration, Polaroid Filt.	" " "		1/1000					
10		" " "	" " "		1/60					
11		" " "	" " "		1/30					
12		" " "	" " "		1/15					
13		" " "	" " "		1/8					
14		" " "	" " "		¼					
15		" " "	" " "		½					
16		" " "	" " "		1					
17		" " "	" " "		3					3.3^{s} actual
18		" " "	" " "		5					
19		" " "	" " "		10					
20		" " "	" " "		20					
21		" " "	" " "		30					
22		" " "	" " "		60					
23		" " "	" " "		90					

APPENDIX D

APOLLO 17 LOW BRIGHTNESS, ASTRONOMICAL PHOTOGRAPHY

Apollo 17 photographic data for these studies were recorded on Eastman Kodak type 2485, high-speed, black-and-white film in two different formats -- 35mm and 70mm, both using emulsion number 108-1. A Nikon camera with 55mm, f/1.2 lens and a Hasselblad electric camera with 80mm, f/2.8 lens provide fields-of-view, respectively, of 35.5° by 24.0° with a 42.9° diagonal and of 36.7° square with a 51.8° diagonal. The Hasselblad low brightness exposures were obtained for Experiment S-210/212, Solar Corona Photography, and they are not included in these tables. However, the 35mm low brightness film does include 132 exposures of the lunar surface, mostly near-terminator photography, 16 exposures of interior Command Module scenes and six exposures of the earthset. Films for both camera formats were calibrated on the High Altitude Observatory's Sensitometer Box No. 2 which provides a solar-referenced, color-corrected illumination of a neutral density step-wedge at f/13.7.

Red, blue and polaroid filters were carried on this mission. These front-end filters were used ahead of the 55mm lens, and the polaroid filter was rotated between two end-stops 90° apart so that plane polarization properties of the white light could be analyzed. The window cutoff and blue filter characteristics established a bandpass of 420 to 510 nanometers; the red filter and emulsion cutoff characteristics established a bandpass of 610 to 700 nanometers. The color and polaroid filters were specifically included to photograph zodiacal light. Unless otherwise specified in the Subject column, all exposures listed recorded the scene in white, unpolarized light. Magazines XX contains eight exposures through filters of the Apollo 17 lunar landing site -- three in red, three in blue and two polaroid.

In the tables which follow, all times are given to the nearest minute. The centers of frames (Cntr Frm Loc) and corners of frames (Crnr Frm Loc) are given when stellar patterns are sufficiently bright for comparison to star charts, or when weak images may be reliably compared to data in adjacent or similar frames. Protect frames refer to individual frames taken at fast shutter speeds to remove data frames from the imaging position in the event of light leaks that could fog data or prefog frames that are to be used for data.

The low brightness, astronomical photographs on 35mm, type 2485 film from Apollo 17 are presented in the order given below:

Flight Mag Desig	NASA Mag Desig	No. of Expos. for Low Bright Astron Photog	No. of Expos. for Lunar Surface Photog	Starts on Page
UU	-156-	Calibrations	-	D-2
VV	-157-	-	31	D-4
WW	-158-	-	41	D-6
XX	-159-	22	16	D-8
YY	-160-	22	25	D-10
ZZ	-161-	Calibrations	19	D-12

NASA Magazine No AS17-156 Magazine Flight Designator UU

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	CNTR FRM LOC RT ASC LONG	CNTR FRM LOC DEC LAT	CRNR FRM LOC RT ASC LONG	CRNR FRM LOC DEC LAT	Remarks
1	23777	Calibration, Red Filter	29 Nov. 1972	-	90	-	-	-	-	
2	23778	" " "	" " "	-	60	-	-	-	-	
3	23779	" " "	" " "	-	40	-	-	-	-	
4	23780	" " "	" " "	-	20	-	-	-	-	
5	23781	" " "	" " "	-	10	-	-	-	-	
6	23782	" " "	" " "	-	6	-	-	-	-	
7	23783	" " "	" " "	-	2	-	-	-	-	
8	23784	" " "	" " "	-	1	-	-	-	-	
9	23785	" " "	" " "	-	1/2	-	-	-	-	
10	23786	" " "	" " "	-	1/4	-	-	-	-	
11	23787	" " "	" " "	-	1/8	-	-	-	-	
12	23788	" " "	" " "	-	1/15	-	-	-	-	
13	23789	" " "	" " "	-	1/30	-	-	-	-	
14	23790	" " "	" " "	-	1/60	-	-	-	-	
15	23791	Calibration, Blue Filter	" " "	-	~ 1	-	-	-	-	
16	23792	" " "	" " "	-	90	-	-	-	-	
17	23793	" " "	" " "	-	60	-	-	-	-	
18	23794	" " "	" " "	-	40	-	-	-	-	
19	23795	" " "	" " "	-	20	-	-	-	-	
20	23796	" " "	" " "	-	10	-	-	-	-	
21	23797	" " "	" " "	-	6	-	-	-	-	
22	23798	" " "	" " "	-	2	-	-	-	-	
23	23799	" " "	" " "	-	1	-	-	-	-	
24	23800	" " "	" " "	-	1/2	-	-	-	-	
25	23801	" " "	" " "	-	1/4	-	-	-	-	
26	23802	" " "	" " "	-	1/8	-	-	-	-	
27	23803	" " "	" " "	-	1/15	-	-	-	-	
28	23804	" " "	" " "	-	1/30	-	-	-	-	
29	23805	" " "	" " "	-	1/60	-	-	-	-	

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	CNTR FRM LOC RT ASC LONG	CNTR FRM LOC DEC LAT	CRNR FRM LOC RT ASC LONG	CRNR FRM LOC DEC LAT	Remarks
30	23806	Calibration, Polaroid Filter	29 Nov. 1972	-	~ 2	-	-	-	-	
31	23807	" " "	" " "	-	90	-	-	-	-	
32	23808	" " "	" " "	-	60	-	-	-	-	
33	23809	" " "	" " "	-	30	-	-	-	-	
34	23810	" " "	" " "	-	20	-	-	-	-	
35	23811	" " "	" " "	-	10	-	-	-	-	
36	23812	" " "	" " "	-	5	-	-	-	-	
37	23813	" " "	" " "	-	3	-	-	-	-	
38	23814	" " "	" " "	-	1	-	-	-	-	
39	23815	" " "	" " "	-	1/2	-	-	-	-	
40	23816	" " "	" " "	-	1/4	-	-	-	-	

NASA Magazine No. AS 17-157   Magazine Flight Designator VV

Film Type 2485   Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	CENTER FRM LOC RT ASC LONG	CENTER FRM LOC DEC LAT	CORNER FRM LOC RT ASC LONG	CORNER FRM LOC DEC LAT	Remarks
1	23817	Interior - Hatch handle				-	-	-	-	
2	23818	LMP off duty				-	-	-	-	
3	23819	LMP off duty				-	-	-	-	
4	23820	CDR eating				-	-	-	-	
5	23821	CMP at center of CM				-	-	-	-	
6	23822	CDR with checklist				-	-	-	-	
7	23823	CMP drinking at G&N Station				-	-	-	-	
8	23824	CMP drinking at G&N Station				-	-	-	-	
9	23825	Protect Frame				-	-	-	-	*
10	23826	Post TEI				118.5°E	41.5° S	127.0°E	33.0°SL	Looking south of Milne
11	23827	Tsiolkovsky				119.0°E	16.0° S	117.5°E	17.0°S	
12	23828	Tsiolkovsky				124.5°E	13.0° S	120.0°E	5.0°SL	Danjon near center
13	23829	Tsiolkovsky				120.0°E	12.0° S	112.0°E	8.0°SL	Langemark in background
14	23830	Fermi Area				122.0°E	14.5° S	119.5°E	17.5°S	
15	23831	Tsiolkovsky, Fermi				125.5°E	16.5° S	123.0°E	13.0°S	
16	23832	Tsiolkovsky, Fermi				124.0°E	17.0° S	121.0°E	15.0°S	Lutke & Delporte upper L.H. area
17	23833	Tsiolkovsky, Fermi				122.5°E	18.0° S	118.5°E	18.0°S	Lutke & Delports upper L.H. area
18	23834	Fermi Area				124.5°E	20.0° S	122.0°E	17.5°S	
19	23835	Fermi Area				123.5°E	19.0° S	121.5°E	17.0°S	
20	23836	Fermi Area				128.0°E	16.5° S	125.0°E	9.0°S	
21	23837	Tsiolkovsky Central Peak				128.5°E	19.5° S	126.5°E	19.0°S	
22	23838	Tsiolkovsky Central Peak				127.5°E	18.5° S	126.0°E	19.0°S	
23	23839	Tsiolkovsky				124.5°E	18.0° S	112.0°E	16.0°SL	Lutke & Delporte upper center
24	23840	Tsiolkovsky				129.5°E	19.0° S	128.5°E	17.5°S	
25	23841	Tsiolkovsky Floor				129.0°E	19.5° S	125.5°E	19.0°S	
26	23842	Mare Imbrium				38.0°W	21.0° N	41.0°W	21.5°N	Braley C and Braley E
27	23843	Mare Imbrium				33.5°W	16.0° N	37.0°W	18.5°N	
28	23844	Mare Imbrium				38.5°W	17.0° N	38.0°W	20.5°N	Bessarion & Bess. A, B, C, E
29	23845	Mare Imbrium Basin				39.0°W	24.0° N	43.5°W	22.0°N	Aristarchus N&D upper L.H.corner
30	23846	Mare Imbrium Basin				37.5°W	26.5° N	46.0°W	25.5°N	Delisle & Diophantes foreground
31	23847	Mare Imbrium Basin				36.0°W	28.0° N	45.5°W	29.0°N	Delisle & Diophantes foreground
32	23848	LMP Closeup				-	-	-	-	
33	23849	LMP Closeup				-	-	-	-	
34	23850	Tsiolkovsky				120.0°E	24.5° S	120.0°E	22.0°S	Zhiritsky near center
35	23851	Tsiolkovsky				125.0°E	19.0° S	128.0°E	18.5°S	
36	23852	Tsiolkovsky Floor				127.5°E	20.0° S	130.5°E	20.0°S	
37	23853	Tsiolkovsky Floor				129.5°E	19.5° S	130.5°E	21.0°S	

* L refers to Lunar Limb

Lunar coordinates are given to nearest 0.5°

NASA Magazine No. AS 17-157 Magazine Flight Designator VV

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	CENTER FRM LOC RT ASC LONG	CENTER FRM LOC DEC LAT	CORNER FRM LOC RT ASC LONG	CORNER FRM LOC DEC LAT	Remarks
38	23854	Tsiolkovsky Floor				129.0°E	20.0° S	130.5°E	21.0°S	
39	23855	Tsiolkovsky Floor				129.5°E	21.0° S	131.5°E	21.0°S	
40	23856	Waterman				129.0°E	24.0° S	128.0°E	23.0°S	
41	23857	CMP				-	-	-	-	
42	23858	CMP				-	-	-	-	
43	23859	CDR, Closeup				-	-	-	-	
44	23860	CDR, Closeup				-	-	-	-	
45	23861	Waterman				126.0°E	26.0° S	130.0°E	33.5°S	
46	23862	Waterman				128.0°E	24.0° S	129.0°E	22.0°S	
47	23862A	Earth's Cusps				-	-	-	-	
48	23862B	Earth's Cusps				-	-	-	-	
49	23862C	Earth's Cusps				-	-	-	-	
50	23862D	Earth's Cusps				-	-	-	-	
51	23862E	Earth's Cusps				-	-	-	-	
52	23862F	Earth's Cusps				-	-	-	-	

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure		Exp. Time (sec)	CENTER FRM LOC		CORNER FRM LOC		Remarks
			Date	GMT		RT ASC LONG	DEC LAT	RT ASC LONG	DEC LAT	
1	23863	Eratosthenes				-	-	-	-	Highly overexposed
2	23864	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
3	23865	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
4	23866	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
5	23867	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
6	23868	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
7	23869	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
8	23870	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
9	23871	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
10	23872	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
11	23873	Eratosthenes				11.5° W	14.5° N	12.5° W	12.5° N	
12	23874	Copernicus				19.5° W	9.5° N	22.0° W	11.5° N	Highly overexposed
13	23875	Copernicus				19.5° W	9.5° N	22.0° W	11.5° N	Highly overexposed
14	23876	Copernicus				19.5° W	9.5° N	22.0° W	11.5° N	Highly overexposed
15	23877	Copernicus				19.5° W	9.5° N	22.0° W	11.5° N	
16	23878	Copernicus				19.5° W	9.5° N	22.0° W	11.5° N	
17	23879	Copernicus				19.5° W	9.5° N	22.0° W	11.5° N	
18	23880	Copernicus				20.0° W	9.5° N	22.0° W	11.5° N	
19	23881	Copernicus				20.0° W	9.5° N	22.0° W	11.5° N	
20	23882	Copernicus				22.5° W	10.5° N	24.0° W	11.0° N	
21	23883	Copernicus				23.5° W	8.5° N	22.5° W	11.0° N	
22	23884	Unknown				-	-	-	-	Highly overexposed
23	23885	Unknown				-	-	-	-	Highly overexposed
24	23886	Reiner				55.0° W	6.0° N	52.0° W	8.0° N	Highly overexposed
25	23887	Reiner				55.0° W	6.0° N	52.0° W	8.0° N	Highly overexposed
26	23888	Reiner & Reiner Y				56.5° W	6.5° N	52.5° W	8.0° N	Highly overexposed
27	23889	Reiner & Reiner Y				57.0° W	6.5° N	53.0° W	8.0° N	Highly overexposed
28	23890	Reiner & Reiner Y				57.5° W	6.5° N	53.0° W	7.5° N	Highly overexposed
29	23891	Reiner & Reiner Y				58.0° W	7.0° N	53.5° W	8.0° N	Overexposed
30	23892	Reiner & Reiner Y				57.5° W	6.5° N	54.0° W	7.5° N	Overexposed
31	23893	Reiner & Reiner Y				57.5° W	6.5° N	54.0° W	7.5° N	
32	23894	Reiner & Reiner Y				57.5° W	7.5° N	54.0° W	7.5° N	
33	23895	Reiner Y				60.5° W	6.5° N	57.0° W	6.5° N	
34	23896	Reiner Y				61.5° W	5.5° N	58.5° W	6.0° N	Cavalerius lower R. H. corner
35	23897	Reiner Y				58.5° W	7.5° N	56.5° W	6.5° N	
36	23898	Reiner Area				63.5° W	4.0° N	61.0° W	5.0° N	Cavalerius foreground
37	23899	Reiner Area				65.5° W	3.0° N	63.5° W	4.5° N	Cavalerius,"Flash" area
38	23900	Grimaldi Area				69.0° W	0.5° S	66.0° W	1.5° N	Lohrmann and Riccioli

NASA Magazine No AS 17-158 Magazine Flight Designator WW

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	CENTER FRM LOC RT ASC LONG	CENTER FRM LOC DEC LAT	CORNER FRM LOC RT ASC LONG	CORNER FRM LOC DEC LAT	Remarks
39	23901	Orientale				83.0° W	12.0° S	83.5° W	9.0° S	Schluter A rim upper L.H. edge
40	23902	Orientale				82.0° W	13.5° S	84.5° W	10.5° S	
41	23903	Orientale				88.0° W	14.5° S	89.5° W	12.0° S	Kopff lower left edge

NASA Magazine No AS 17-159 Magazine Flight Designator XX

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	CENTER FRM LOC RT ASC LONG	CENTER FRM LOC DEC LAT	CORNER FRM LOC RT ASC LONG	CORNER FRM LOC DEC LAT	Remarks
1	23904	Protect Frame	12 Dec'72	-	1/1000	-	-	-	-	
2	23905	Zodiacal Light, Red Filter	12 Dec'72	1523	90	$21^h\ 40^m$	-30°	$23^h\ 20^m$	-27°	
3	23906	Zodiacal Light, Red Filter	12 Dec'72	1527	60	$21^h\ 05^m$	-30°	$22^h\ 40^m$	-28°	
4	23907	Zodiacal Light, Red Filter	12 Dec'72	1530	~1	-	-	-	-	Too faint
5	23908	Zodiacal Light, Red Filter	12 Dec'72	1532	40	$19^h\ 42^m$	-31°	$21^h\ 30^m$	-36°	Bright Object - Jupiter
6	23909	Zodiacal Light, Red Filter	12 Dec'72	1534	20	$19^h\ 08^m$	-29°	$21^h\ 00^m$	-36°	Bright Object - Jupiter
7	23910	Zodiacal Light, Red Filter	12 Dec'72	1535	10	$18^h\ 55^m$	-28°	$20^h\ 35^m$	-37°	Bright Object - Jupiter
8	23911	Zodiacal Light, Red Filter	12 Dec'72	1536	6	$18^h\ 50^m$	-28°	$20^h\ 25^m$	-37°	Bright Object - Jupiter
9	23912	Zodiacal Light, Red Filter	12 Dec'72	1536	2	$18^h\ 50^m$	-27°	$20^h\ 20^m$	-36°	Bright Object - Jupiter
10	23913	Zodiacal Light, Red Filter	12 Dec'72	1536	1/2	$18^h\ 50^m$	-26°	$20^h\ 15^m$	-36°	Bright Object - Jupiter
11	23914	Zodiacal Light, Red Filter	12 Dec'72	1537	1/8	$18^h\ 45^m$	-26°	$20^h\ 10^m$	-36°	Bright Object - Jupiter
12	23915	Zodiacal Light, Red Filter	12 Dec'72	1538	1/30	$18^h\ 45^m$	-26°	$20^h\ 10^m$	-36°	Bright Object - Jupiter
13	23916	Protect Frame	12 Dec'72	-	1/1000	-	-	-	-	
14	23917	Aitken				173.5°E	17.0° S	175.0° E	17.5° S	
15	23918	Littrow Area, Red Filter				31.0°E	20.0° N	33.5° E	20.5° N	
16	23919	Littrow Area, Red Filter				31.0°E	20.0° N	33.5° E	20.5° N	Lens f/16, Overexposed
17	23920	Littrow Area, Red Filter				31.0°E	20.0° N	33.0° E	20.5° N	Lens f/16, Overexposed
18	23921	Littrow Area, Blue Filter				31.0°E	20.0° N	33.0° E	20.5° N	Lens f/16, Overexposed
19	23922	Littrow Area, Blue Filter				31.0°E	20.0° N	33.0° E	20.5° N	Lens f/16, Overexposed
20	23923	Littrow Area, Blue Filter				31.0°E	20.0° N	32.5° E	21.0° N	Lens f/16, Littrow
21	23924	Littrow Area, Polaroid Filter				30.5°E	20.0° N	32.5° E	21.0° N	Lens f/16, Littrow
22	23925	Littrow Area, Polaroid Filter				30.5°E	20.0° N	32.5° E	21.0° N	Lens f/16, Littrow
23	23926	Littrow Area				29.0°E	22.0° N	30.0° E	24.0° N	Lens f/16, Rima Littrow VII
24	23927	Littrow Area				29.0°E	22.0° N	30.0° E	24.5° N	Lens f/16, Rima Littrow VII
25	23928	Sulpicius Gallus				10.5°E	21.5° N	11.0° E	20.0° N	
26	23929	Sulpicius Gallus				8.0°E	24.5° N	11.0° E	27.0° N	
27	23930	Sulpicius Gallus				9.0°E	26.0° N	12.5° E	23.0° N	
28	23931	Manilius E				5.5°E	18.5° N	7.0° E	18.5° N	D Caldera
29	23932	Aitken				173.5°E	17.0° S	172.0° E	18.0° S	
30	23933	Protect Frame	13 Dec'72	-	1/1000	-	-	-	-	
31	23934	Zodiacal Light, Blue Filter	13 Dec'72	2206	90	$21^h\ 45^m$	-30°	$23^h\ 20^m$	-25°	Bright Object - Jupiter
32	23935	Zodiacal Light, Blue Filter	13 Dec'72	2210	60	$20^h\ 50^m$	-30°	$22^h\ 30^m$	-32°	Bright Object - Jupiter
33	23936	Zodiacal Light, Blue Filter	13 Dec'72	2213	60	$20^h\ 10^m$	-30°	$22^h\ 00^m$	-31°	Bright Object - Jupiter
34	23937	Zodiacal Light, Blue Filter	13 Dec'72	2215	40	$19^h\ 45^m$	-30°	$21^h\ 35^m$	-33°	Bright Object - Jupiter
35	23938	Zodiacal Light, Blue Filter	13 Dec'72	2216	20	$19^h\ 30^m$	-29°	$20^h\ 50^m$	-32°	Bright Object - Jupiter
36	23939	Zodiacal Light, Blue Filter	13 Dec'72	2218	10	$19^h\ 15^m$	-29°	$20^h\ 50^m$	-32°	Bright Object - Jupiter
37	23940	Zodiacal Light, Blue Filter	13 Dec'72	2218	6	$19^h\ 15^m$	-28°	$20^h\ 50^m$	-33°	Bright Object - Jupiter

NASA Magazine No. AS 17-159 Magazine Flight Designator XX

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure		Exp. Time (sec)	CENTER FRM LOC		CORNER FRM LOC		Remarks
			Date	GMT		RT ASC LONG	DEC LAT	RT ASC LONG	DEC LAT	
38	23941	Zodiacal Light, Blue Filter	13 Dec'72	2219	2	$19^h\ 10^m$	-28^o	$20^h\ 35^m$	-31^o	Bright Object - Jupiter
39	23942	Zodiacal Light, Blue Filter	13 Dec'72	2219	1	$19^h\ 10^m$	-28^o	$20^h\ 35^m$	-31^o	Bright Object - Jupiter
40	23943	Zodiacal Light, Blue Filter	13 Dec'72	2219	1/8	$19^h\ 00^m$	-27^o	$20^h\ 30^m$	-31^o	Bright Object - Jupiter
41	23944	Zodiacal Light, Blue Filter	13 Dec'72	2220	1/30	$18^h\ 50^m$	-27^o	$20^h\ 25^m$	-31^o	Bright Object - Jupiter
42	23945	Protect Frame	13 Dec'72	-	1/1000	-	-	-	-	

NASA Magazine No. AS 17-160 Magazine Flight Designator YY

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	CENTER FRM LOC RT ASC LONG	DEC LAT	CORNER FRM LOC RT ASC LONG	DEC LAT	Remarks
1	23946	Eratosthenes				6.5°W	14.5° N	6.5°W	17.5° N	Marco Polo C
2	23947	Timocharis				10.5°W	25.0° N	6.5°W	26.0° N	
3	23948	Beijerick				153.0°E	15.0° S	156.0°E	16.5° S	Gagarin on right edge
4	23949	Agassiz				148.0°E	17.5° S	151.0°E	17.0° S	
5	23950	Jules Verne				147.0°E	25.0° S	143.0°E	36.0° S	Pavlov in background
6	23951	Jules Verne				148.5°E	26.0° S	151.0°E	41.0° S	Pavlov at upper R.H. edge
7	23952	Protect Frame	14 Dec'72	-	1/1000	-	-	-	-	
8	23953	Zodiacal Light, Polaroid	14 Dec'72	1953	90	$21^h 45^m$	-12°	$22^h 55^m$	+2°	
9	23954	Zodiacal Light, Polaroid	14 Dec'72	1955	90	$21^h 15^m$	-15°	$22^h 10^m$	+3°	
10	23955	Zodiacal Light, Polaroid	14 Dec'72	1957	60	$20^h 50^m$	-18°	$21^h 55^m$	-4°	
11	23956	Zodiacal Light, Polaroid	14 Dec'72	1959	60	$20^h 35^m$	-18°	$21^h 35^m$	-3°	
12	23957	Zodiacal Light, Polaroid	14 Dec'72	2000	30	$20^h 15^m$	-19°	$21^h 30^m$	-3°	
13	23958	Zodiacal Light, Polaroid	14 Dec'72	2001	30	$20^h 05^m$	-20°	$21^h 20^m$	-1°	
14	23959	Zodiacal Light, Polaroid	14 Dec'72	2002	20	$19^h 50^m$	-21°	$20^h 55^m$	-4°	Bright Object - Jupiter
15	23960	Zodiacal Light, Polaroid	14 Dec'72	2003	20	$19^h 45^m$	-20°	$20^h 55^m$	-4°	Bright Object - Jupiter
16	23961	Zodiacal Light, Polaroid	14 Dec'72	2004	10	$19^h 35^m$	-21°	$20^h 45^m$	-2°	Bright Object - Jupiter
17	23962	Zodiacal Light, Polaroid	14 Dec'72	2004	10	$19^h 25^m$	-21°	$20^h 40^m$	-5°	Bright Object - Jupiter
18	23963	Zodiacal Light, Polaroid	14 Dec'72	2005	5	$19^h 15^m$	-21°	$20^h 05^m$	-7°	Bright Object - Jupiter
19	23964	Zodiacal Light, Polaroid	14 Dec'72	2006	5	$19^h 15^m$	-21°	$20^h 15^m$	-4°	Bright Object - Jupiter
20	23965	Zodiacal Light, Polaroid	14 Dec'72	2006	3	$19^h 10^m$	-21°	$20^h 00^m$	-4°	Bright Object - Jupiter
21	23966	Zodiacal Light, Polaroid	14 Dec'72	2006	3	$19^h 10^m$	-21°	$20^h 00^m$	-4°	Bright Object - Jupiter
22	23967	Zodiacal Light, Polaroid	14 Dec'72	2006	1	$19^h 05^m$	-21°	$20^h 00^m$	-4°	Bright Object - Jupiter
23	23968	Zodiacal Light, Polaroid	14 Dec'72	2006	1	$19^h 00^m$	-21°	$20^h 00^m$	-4°	Bright Object - Jupiter
24	23969	Zodiacal Light, Polaroid	14 Dec'72	2007	1/4	$19^h 00^m$	-21°	$20^h 00^m$	-4°	Bright Object - Jupiter
25	23970	Zodiacal Light, Polaroid	14 Dec'72	2007	1/4	$19^h 00^m$	-21°	$20^h 00^m$	-4°	Bright Object - Jupiter
26	23971	Zodiacal Light, Polaroid	14 Dec'72	2007	1/15	$19^h 00^m$	-21°	$20^h 00^m$	-4°	Bright Object - Jupiter
27	23972	Zodiacal Light, Polaroid	14 Dec'72	2007	1/15	$18^h 55^m$	-21°	$19^h 55^m$	-4°	Bright Object - Jupiter
28	23973	Zodiacal Light, Polaroid	14 Dec'72	2007	1/60	$18^h 55^m$	-21°	$19^h 55^m$	-4°	Bright Object - Jupiter
29	23974	Zodiacal Light, Polaroid	14 Dec'72	2007	1/60	$18^h 55^m$	-21°	$19^h 55^m$	-4°	Bright Object - Jupiter
30	23975	Protect Frame	14 Dec'72	2007	1/1000	-	-	-	-	
31	23976	Jules Verne				146.5°E	27.5° S	143.0°E	24.5° S	Jules Verne and Pavlov
32	23977	Jules Verne				143.5°E	25.5° S	141.0°E	23.0° S	Pavlov lower L.H. corner
33	23978	Agassiz				144.5°E	17.5° S	153.0°E	11.0° S	
34	23979	Lambert				21.5°W	24.0° N	21.0°W	26.0° N	
35	23980	Euler				31.0°W	24.0° N	28.0°W	27.0° N	
36	23981	Euler Hills				29.0°W	16.0° N	25.0°W	10.0° N	Tobias Mayer
37	23982	Euler Hills				30.0°W	17.0° N	30.0°W	20.0° N	Tobias Mayer
38	23983	Euler Hills				31.0°W	20.5° N	29.5°W	23.0° N	Euler P near center

NASA Magazine No. AS 17-160   Magazine Flight Designator YY

Film Type 2485   Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	Time of Exposure GMT	Exp. Time (sec)	CENTER FRM LOC RT ASC LONG	CENTER FRM LOC DEC LAT	CORNER FRM LOC RT ASC LONG	CORNER FRM LOC DEC LAT	Remarks
39	23984	Blank				-	-	-	-	
40	23985	Overexposure				-	-	-	-	
41	23986	Overexposure				-	-	-	-	
42	23987	Tsiolkovsky				137.0°E	27.0° S	132.0°E	37.0° SL	
43	23988	Tsiolkovsky				133.0°E	22.0° S	130.0°E	24.0° S	
44	23989	Waterman				129.0°E	24.5° S	123.0°E	32.0° SL	
45	23990	Tsiolkovsky				128.0°E	19.5° S	127.0°E	19.0° S	
46	23991	Euler Hills				27.5°W	17.0° N	31.5°W	17.5° N	Tobias Mayer
47	23992	Euler Hills				31.0°W	19.0° N	33.5°W	20.0° N	Euler P near center
48	23993	Euler Hills				34.0°W	15.0° N	37.0°W	19.0° N	Tobias Mayer W
49	23994	Euler Hills				36.0°W	14.5° N	39.5°W	16.5° N	Tobias Mayer W,Bessarion &Bess.E
50	23995	Euler Hills				38.0°W	16.5° N	45.0°W	21.0° N	Bessarion and Bessarion E
51	23996	CDR, Closeup				-	-	-	-	
52	23997	CMP at G & N Station				-	-	-	-	

NASA Magazine No. AS 17-161 Magazine Flight Designator ZZ

Film Type 2485 Film Size 35 mm

Quick Look Fr No	NASA Frame No.	Subject	Time of Exposure Date	GMT	Exp. Time (sec)	CENTER FRM LOC RT ASC LONG	DEC LAT	CORNER FRM LOC RT ASC LONG	DEC LAT	Remarks
1	23998	Riccioli				71.0^{o}W	1.5^{o} S	73.0^{o} W	3.0^{o} SL	
2	23999	Riccioli				70.5^{o}W	1.0^{o} S	73.0^{o} W	3.0^{o} SL	
3	24000	Riccioli				71.0^{o}W	2.0^{o} S	74.0^{o} W	1.0^{o} S	
4	24001	Riccioli				70.0^{o}W	1.5^{o} S	73.5^{o} W	2.0^{o} S	
5	24002	Riccioli				71.5^{o}W	0.5^{o} S	83.0^{o} W	0.0^{o}	Double Crater-Riccioli C
6	24003	Riccioli				71.0^{o}W	1.5^{o} S	73.0^{o} W	2.0^{o} S	
7	24004	Riccioli G				71.0^{o}W	2.0^{o} S	73.5^{o} W	2.0^{o} S	
8	24005	Riccioli G				72.5^{o}W	1.0^{o} S	75.0^{o} W	1.0^{o} S	
9	24006	Riccioli G				71.0^{o}W	0.5^{o} S	72.5^{o} W	0.0^{o}	
10	24007	Riccioli G				70.5^{o}W	2.0^{o} S	72.0^{o} W	0.5^{o} S	
11	24008	Riccioli				74.0^{o}W	1.5^{o} S	78.0^{o} W	1.0^{o} N	
12	24009	Riccioli				75.5^{o}W	1.0^{o} S	78.5^{o} W	1.0^{o} N	
13	24010	Schluter A				79.0^{o}W	6.0^{o} S	88.0^{o} W	9.0^{o} SL	Schluter & Hartwig A
14	24011	Schluter A				76.0^{o}W	3.5^{o} S	77.5^{o} W	3.5^{o} S	
15	24012	Schluter A				77.0^{o}W	11.5^{o} S	79.0^{o} W	8.5^{o} S	
16	24013	Schluter				82.5^{o}W	6.0^{o} S	81.0^{o} W	7.0^{o} S	
17	24014	Schluter				83.0^{o}W	5.5^{o} S	82.0^{o} W	7.0^{o} S	
18	24015	Mare Orientale				90.5^{o}W	9.0^{o} S	99.0^{o} W	14.0^{o} S	
19	24016	Mare Orientale				90.0^{o}W	14.5^{o} S	90.0^{o} W	28.0^{o} SL	Kopff
20	24017	Calibration, Polaroid Filter	29 Nov'72		1/8	-	-	-	-	
21	24018	Calibration, Polaroid Filter	29 Nov'72		1/15	-	-	-	-	
22	24019	Calibration, Polaroid Filter	29 Nov'72		1/30	-	-	-	-	
23	24020	Calibration, Polaroid Filter	29 Nov'72		1/60	-	-	-	-	
24	24021	Calibration, ND 2 Filter	29 Nov'72		300	-	-	-	-	
25	24022	Calibration, ND 2 Filter	29 Nov'72		180	-	-	-	-	
26	24023	Calibration, ND 2 Filter	29 Nov'72		60	-	-	-	-	
27	24024	Calibration, No Filter	29 Nov'72		60	-	-	-	-	
28	24025	Calibration, No Filter	29 Nov'72		20	-	-	-	-	
29	24026	Calibration, No Filter	29 Nov'72		6	-	-	-	-	
30	24027	Calibration, No Filter	29 Nov'72		2	-	-	-	-	
31	24028	Calibration, No Filter	29 Nov'72		1	-	-	-	-	
32	24029	Calibration, No Filter	29 Nov'72		1/2	-	-	-	-	
33	24030	Calibration, No Filter	29 Nov'72		1/4	-	-	-	-	
34	24031	Calibration, No Filter	29 Nov'72		1/8	-	-	-	-	
35	24032	Calibration, No Filter	29 Nov'72		1/15	-	-	-	-	
36	24033	Calibration, No Filter	29 Nov'72		1/30	-	-	-	-	
37	24034	Calibration, No Filter	29 Nov'72		1/60	-	-	-	-	

APPENDIX E

PROCESSED FLIGHT AND CALIBRATION DATA

Listings are presented of all flight data and calibration frames on which digital photodensitometry has been performed as of 31 Dec 74. Certain data appearing in prior appendices is repeated here to simplify the identification of important technical parameters. Column headings and their meaning are as follows:

1. Subject . . . . Description of actual or intended subject.
2. Data and GMT Time . . Self-explanatory.
3. Mg Dg . . . . Flight magazine or cassette designation letters.
4. QL Numb . . . . Quick-Look frame number.
5. NASA Frame Number . . Self-explanatory. This column is not included for Apollo 14 data (See page A-1).
6. Cam & Frmt . . . . . Camera type and film width in mm.
   D 16 - Data Acquisition Camera with 16mm film.
   N 35 - Nikon Camera with 35mm film.
   H 70 - Hasselblad Electric Camera with 70mm film.
7. Lens FL & f/No . . . Lens focal length and f/number setting.
8. Exp Time . . . . . . Frame exposure time.
9. Cnt Frm Loc . . . . . Celestial location of frame center in Right
   RtAsc Dec — Ascension (hrs:min) and Declination (Deg).
10. Photodensitometry Digitization Data:
    a) Tape Dg . . . . . Magnetic tape designation for frames processed on a Perkin-Elmer Photometric Data Systems Automatic Recording Microdensitometer, Model 1010A.
    b) Fi . . . . Number of the file containing header data and digitized array of photodensitometered values.
    c) Ap Sz . . . . . . Length of square aperture side used in photodensitometry and given in microns. All digitizations covered 100% of scanned image area with no overlap. Approximate spot size if only read on Dicomed digitizing photodensitometer.
    d) DM . . . . Indicates data also processed on a Dicomed Image Digitizer, Model 57.
    e) Numb Line . . . . Number of lines in photodensitometry scan of frame.
    f) Numb Samp . . . . Number of densitometer reading samples per line.
11. VICAR Format & Other Proc:
    a) Tape Dg . . . . . Magnetic tape designation for VICAR formatted data.
    b) Fi . . . . Number of the file containing header data and VICAR formatted conversion of photodensitometered values.
    c) Cn . . . . VICAR formatting, production of histogram and Photometer output for data quality verification.

PROCESSED FLIGHT AND CALIBRATION DATA FROM APOLLO 14

Subject	Date and GMT Time	Mg Dg	QL Numb	Cam& LensFL Frmt & f/No	Exp Time	CntFrmLoc RtAsc Dec	Photodensitometry Digitization Data Tape Dg	Fi	Ap Sz	D M	Numb Line	Numb Samp	VICAR Format & Other Proc Tape Dg	Fi	C n
Calibration, Preflt.	26 Jan 71 0431	J	0021	D 16 18,.95	60		S211 08	4	35		360	228	S211 27	4	
Calibration, Preflt.	26 Jan 71 0432	J	0024	D 16 18,.95	20		S211 08	6	35		360	228	S211 27	6	
Calibration, Preflt.	26 Jan 71 0432	J	0027	D 16 18,.95	5		S211 08	9	35		360	228	S211 27	9	
Calibration, Preflt.	26 Jan 71 0433	J	0030	D 16 18,.95	60				35	X	1024	1024			
Calibration, Preflt.	26 Jan 71 0434	J	0033	D 16 18,.95	20				35	X	1024	1024			
Calibration, Preflt.	26 Jan 71 0434	J	0036	D 16 18,.95	5				35	X	1024	1024			
Zodiacal Light	5 Feb 71 1428	J	0963	D 16 18,.95	5	2^h55^m+15	S211 08	12	35		360	228	S211 27	12	
Zodiacal Light	5 Feb 71 1428	J	0964	D 16 18,.95	20	2^h55^m+15	S211 08	13	35	X	360	228	S211 27	13	
Zodiacal Light	5 Feb 71 1428	J	0965	D 16 18,.95	5	2^h55^m+15	S211 08	14	35		360	228	S211 27	14	
Zodiacal Light	5 Feb 71 1429	J	0967	D 16 18,.95	16	2^h45^m+14	S211 08	15	35	X	360	228	S211 27	15	
Zodiacal Light	5 Feb 71 1429	J	0968	D 16 18,.95	8	2^h40^m+14	S211 08	16	35		360	228	S211 27	16	
Zodiacal Light	5 Feb 71 1430	J	0969	D 16 18,.95	20	2^h05^m+10	S211 08	17	35	X	360	228	S211 27	17	
Zodiacal Light	5 Feb 71 1430	J	0970	D 16 18,.95	16	2^h05^m+11	S211 08	18	35		360	228	S211 27	18	
Zodiacal Light	5 Feb 71 1430	J	0971	D 16 18,.95	4	2^h00^m+13	S211 08	19	35		360	228	S211 27	19	
Zodiacal Light	5 Feb 71 1431	J	0972	D 16 18,.95	16	2^h05^m+10	S211 08	20	35	X	360	228	S211 27	20	
Zodiacal Light	5 Feb 71 1431	J	0973	D 16 18,.95	8	2^h05^m+10	S211 08	21	35		360	228	S211 27	21	
Zodiacal Light	5 Feb 71 1432	J	0977	D 16 18,.95	16	1^h20^m+08	S211 08	22	35	X	360	228	S211 27	22	
Zodiacal Light	5 Feb 71 1432	J	0978	D 16 18,.95	8	1^h20^m+08			35	X	1024	1024			
Lunar Libration L_4	6 Feb 71 1031	J	1471	D 16 18,.95	60	13^h50^m-17			35	X	1024	1024			

PROCESSED FLIGHT AND CALIBRATION DATA FROM APOLLO 15

Subject	Date and GMT Time	Mg Dg	QL No	NASA Frame Number	Cam& Frmt LensFL & f/No	Exp Tim	CntFrmLoc RtAsc Dec	Photodensitometry Digitization Data Tape	Dg	Fi	Ap Sz	D M	Numb Line	Numb Samp	VICAR Format & Other Proc Tape	Dg	Fi	C n
Lunar Libration L_4	31 Jul 71 1337	T	5	AS15-101-13566	N 35 55,1.2	240	23^h15^m-03	S211	04	15	35	X	800	1143	S211	24	14	X
Zodiacal Light, 75°E	1 Aug 71 1334	U	7	AS15-100-13513	N 35 55,1.2	120	14^h05^m-36	S211	04	11	35	X	560	860	S211	24	11	X
Zodiacal Light, 65°E	1 Aug 71 1337	U	9	AS15-100-13515	N 35 55,1.2	120	13^h35^m-32	S211	04	13	35	X	850	970	S211	24	12	X
Zodiacal Light, 55°E	1 Aug 71 1341	U	11	AS15-100-13517	N 35 55,1.2	90	12^h55^m-29	S211	04	14	35	X	860	975	S211	24	13	X
Zodiacal Light, 45°E	1 Aug 71 1344	U	14	AS15-100-13520	N 35 55,1.2	90	12^h30^m-25	S211	05	1	35	X	850	1001				
Zodiacal Light, 35°E	1 Aug 71 1347	U	19	AS15-100-13525	N 35 55,1.2	60	12^h00^m-14	S211	05	2	35	X	870	1001				
Zodiacal Light, 35°E	1 Aug 71 1348	U	20	AS15-100-13526	N 35 55,1.2	20	11^h55^m-13	S211	05	3	35	X	800	1143				
Zodiacal Light, 25°E	1 Aug 71 1351	U	22	AS15-100-13528	N 35 55,1.2	60	11^h35^m 0	S211	05	4	35	X	800	1143	S211	25	6	X
Zodiacal Light, 25°E	1 Aug 71 1352	U	23	AS15-100-13529	N 35 55,1.2	20	11^h30^m+07	S211	05	5	35	X	800	1143	S211	25	7	X
Zodiacal Light, 15°E	1 Aug 71 1354	U	25	AS15-100-13531	N 35 55,1.2	30	11^h10^m+11	S211	05	6	35	X	800	1143	S211	25	8	X
Zodiacal Light, 15°E	1 Aug 71 1355	U	26	AS15-100-13532	N 35 55,1.2	10	11^h10^m+13	S211	05	7	35	X	800	1143	S211	25	9	
Calibration, Preflt.	18 Jul 71	W	1		N 35 -,13.7	240		S211	04	4	35	X	100	629	S211	24	4	
Calibration, Preflt.	18 Jul 71	W	6		N 35 -,13.7	120		S211	04	5	35	X	100	629	S211	24	5	
Calibration, Preflt.	18 Jul 71	W	7		N 35 -,13.7	90		S211	04	6	35	X	100	629	S211	24	6	
Calibration, Preflt.	18 Jul 71	W	10		N 35 -,13.7	60		S211	04	7	35	X	100	629	S211	24	7	
Calibration, Preflt.	18 Jul 71	W	11		N 35 -,13.7	30		S211	04	8	35	X	100	629	S211	24	8	
Calibration, Preflt.	18 Jul 71	W	14		N 35 -,13.7	20		S211	04	9	35	X	100	629	S211	24	9	
Calibration, Preflt.	18 Jul 71	W	18		N 35 -,13.7	10		S211	04	10	35	X	100	629	S211	24	10	
Calibration, Preflt.	18 Jul 71	R			H 70 -,13.7	1/8		S211	01	3	35		772	86	S211	26	3	
Calibration, Preflt.	18 Jul 71	R			H 70 -,13.7	1/4		S211	01	2	35		772	86	S211	26	2	
Calibration, Preflt.	18 Jul 71	R			H 70 -,13.7	1		S211	01	1	35	X	772	86	S211	26	1	
Solar Corona, Sunrise	31 Jul 71 1159	R	2	AS15-98-13310	H 70 80,2.8	1		S211	01	4	35	X	1743	829	S211	26	4	
Solar Corona, Sunrise	31 Jul 71 1159	R	3	AS15-98-13311	H 70 80,2.8	10	9^h20^m+13	S211	01	5	35	X	1743	1629	S211	26	5	
Solar Corona, Sunset	31 Jul 71 1312	R	16	AS15-98-13324	H 70 80,2.8	1		S211	03	5	35	X	920	1772	S211	28	5	
Solar Corona, Sunset	31 Jul 71 1312	R	17	AS15-98-13325	H 70 80,2.8	10	7^h55^m+38	S211	01	7	35	X	1828	1429	S211	26	7	
Solar Corona, Sunrise	4 Aug 71 0845	R	18	AS15-98-13377	H 70 80,2.8	1		S211	03	1	35		1264	858	S211	28	1	

PROCESSED FLIGHT AND CALIBRATION DATA FROM APOLLO 16

Subject	Date and GMT Time	Mg Dg	QL No	NASA Frame Number	Cam& LensFL Frmt & f/No	Exp Tim	CntFrmLoc RtAsc Dec	Photodensitometry Digitization Data Tape Dg	Fi	Ap Sz	D M	Numb Line	Numb Samp	VICAR Format & Other Proc Tape Dg	Fi	C n
Calibration, ND3.0 Filt.	10 Apr 72	W	3		N 35 -,13.7	180		ISSR 20	1	80	X	100	337	ISSR 22	1	
Calibration, ND3.0 Filt.	10 Apr 72	W	4		N 35 -,13.7	180		ISSR 20	2	80		100	337	ISSR 22	2	
Calibration, Red Filt.	10 Apr 72	Y	1		N 35 -,13.7	240		ISSR 20	3	80	X	100	337	ISSR 22	3	
Calibration, Red Filt.	10 Apr 72	Y	2		N 35 -,13.7	240		ISSR 20	4	80		100	337	ISSR 22	4	
Calibration, Red Filt.	10 Apr 72	Y	3		N 35 -,13.7	60		ISSR 20	5	80		100	337	ISSR 22	5	
Calibration, Red Filt.	10 Apr 72	Y	4		N 35 -,13.7	60		ISSR 20	6	80		100	337	ISSR 22	6	
Calibration, Blue Filt.	10 Apr 72	Y	5		N 35 -,13.7	240		ISSR 20	7	80	X	100	337	ISSR 22	7	
Calibration, Blue Filt.	10 Apr 72	Y	6		N 35 -,13.7	240		ISSR 20	8	80		100	337	ISSR 22	8	
Calibration, Blue Filt.	10 Apr 72	Y	7		N 35 -,13.7	60		ISSR 20	9	80		100	337	ISSR 22	9	
Calibration, Blue Filt.	10 Apr 72	Y	8		N 35 -,13.7	60		ISSR 20	10	80		100	337	ISSR 22	10	
Gegenschein, Moulton Reg	22 Apr 72 1619	ZZ	10	AS16-126-19970	N 35 55,1.2	180	13^h50^m-10	ISSR 20	11	80	X	332	458	ISSR 22	11	
Gegenschein, Moulton Reg	22 Apr 72 1623	ZZ	11	AS16-126-19969	N 35 55,1.2	180	14^h25^m-12	ISSR 20	12	80	X	332	458	ISSR 22	12	
Gegenschein, Moulton Reg	22 Apr 72 1629	ZZ	13	AS16-126-19967	N 35 55,1.2	180	15^h00^m-18	ISSR 20	13	80	X	332	458	ISSR 22	13	
Gum Nebula, Pt.2, Red	24 Apr 72 2142	ZZ	17	AS16-126-19963	N 35 55,1.2	240	8^h40^m-52	ISSR 20	14	80	X	332	458	ISSR 22	14	
Gum Nebula, Pt.2, Red	24 Apr 72 2146	ZZ	18	AS16-126-19962	N 35 55,1.2	60	8^h30^m-53	ISSR 20	15	80		332	458	ISSR 22	15	
Gum Nebula, Pt.2, Blue	24 Apr 72 2148	ZZ	19	AS16-126-19961	N 35 55,1.2	60	8^h40^m-51	ISSR 20	16	80		332	458	ISSR 22	16	
Gum Nebula, Pt.2, Blue	24 Apr 72 2151	ZZ	21	AS16-126-19959	N 35 55,1.2	240	8^h35^m-51	ISSR 20	17	80	X	332	458	ISSR 22	17	
Gegenschein, Moulton Reg	25 Apr 72 0342	ZZ	26	AS16-126-19954	N 35 55,1.2	180	14^h55^m-19	ISSR 20	18	80	X	332	458	ISSR 22	18	
Gegenschein, Moulton Reg	25 Apr 72 0347	ZZ	28	AS16-126-19952	N 35 55,1.2	180	14^h30^m-16	ISSR 20	19	80	X	332	458	ISSR 22	19	

PROCESSED FLIGHT AND CALIBRATION DATA FROM APOLLO 17

Subject	Date and GMT Time	Mg Dg	QL No	NASA Frame Number	Cam& LensFL Frmt & f/No	Exp Tim	CntFrmLoc RtAsc Dec	Photodensitometry Digitization Data Tape Dg	Fi	Ap Sz	D M	Numb Line	Numb Samp	VICAR Format & Other Proc Tape Dg	Fi	C n
Calibration, Red Filt.	29 Nov 72	UU	1	AS17-156-23777	N 35 -,13.7	90		ISSR 08	1	80		100	337	ISSR 10	1	
Calibration, Red Filt.	29 Nov 72	UU	2	AS17-156-23778	N 35 -,13.7	60		ISSR 08	2	80		100	337	ISSR 10	2	
Calibration, Red Filt.	29 Nov 72	UU	3	AS17-156-23779	N 35 -,13.7	40		ISSR 08	3	80		100	337	ISSR 10	3	
Calibration, Red Filt.	29 Nov 72	UU	4	AS17-156-23780	N 35 -,13.7	20		ISSR 08	4	80		100	337	ISSR 10	4	
Calibration, Red Filt.	29 Nov 72	UU	5	AS17-156-23781	N 35 -,13.7	10		ISSR 08	5	80		100	337	ISSR 10	5	
Calibration, Red Filt.	29 Nov 72	UU	6	AS17-156-23782	N 35 -,13.7	6		ISSR 08	6	80		100	337	ISSR 10	6	
Calibration, Red Filt.	29 Nov 72	UU	7	AS17-156-23783	N 35 -,13.7	2		ISSR 08	7	80		100	337	ISSR 10	7	
Calibration, Red Filt.	29 Nov 72	UU	9	AS17-156-23785	N 35 -,13.7	1/2		ISSR 08	8	80		100	337	ISSR 10	8	
Calibration, Blue Filt.	29 Nov 72	UU	16	AS17-156-23792	N 35 -,13.7	90		ISSR 08	9	80		100	337	ISSR 10	9	
Calibration, Blue Filt.	29 Nov 72	UU	17	AS17-156-23793	N 35 -,13.7	60		ISSR 08	10	80		100	337	ISSR 10	10	
Calibration, Blue Filt.	29 Nov 72	UU	18	AS17-156-23794	N 35 -,13.7	40		ISSR 08	11	80		100	337	ISSR 10	11	
Calibration, Blue Filt.	29 Nov 72	UU	19	AS17-156-23795	N 35 -,13.7	20		ISSR 08	12	80		100	337	ISSR 10	12	
Calibration, Blue Filt.	29 Nov 72	UU	20	AS17-156-23796	N 35 -,13.7	10		ISSR 08	13	80		100	337	ISSR 10	13	
Calibration, Blue Filt.	29 Nov 72	UU	21	AS17-156-23797	N 35 -,13.7	6		ISSR 08	14	80		100	337	ISSR 10	14	
Calibration, Blue Filt.	29 Nov 72	UU	22	AS17-156-23798	N 35 -,13.7	2		ISSR 08	15	80		100	337	ISSR 10	15	
Calibration, Blue Filt.	29 Nov 72	UU	23	AS17-156-23799	N 35 -,13.7	1		ISSR 08	16	80		100	337	ISSR 10	16	
Calibration, Blue Filt.	29 Nov 72	UU	26	AS17-156-23802	N 35 -,13.7	1/8		ISSR 08	17	80		100	337	ISSR 10	17	
Calibration, Polaroid	29 Nov 72	UU	31	AS17-156-23807	N 35 -,13.7	90		ISSR 08	18	80		100	337	ISSR 10	18	
Calibration, Polaroid	29 Nov 72	UU	32	AS17-156-23808	N 35 -,13.7	60		ISSR 08	19	80		100	337	ISSR 10	19	
Calibration, Polaroid	29 Nov 72	UU	33	AS17-156-23809	N 35 -,13.7	30		ISSR 08	20	80		100	337	ISSR 10	20	
Calibration, Polaroid	29 Nov 72	UU	34	AS17-156-23810	N 35 -,13.7	20		ISSR 08	21	80		100	337	ISSR 10	21	
Calibration, Polaroid	29 Nov 72	UU	35	AS17-156-23811	N 35 -,13.7	10		ISSR 08	22	80		100	337	ISSR 10	22	
Calibration, Polaroid	29 Nov 72	UU	36	AS17-156-23812	N 35 -,13.7	5		ISSR 08	23	80		100	337	ISSR 10	23	
Calibration, Polaroid	29 Nov 72	UU	37	AS17-156-23813	N 35 -,13.7	3		ISSR 08	24	80		100	337	ISSR 10	24	
Calibration, Polaroid	29 Nov 72	UU	38	AS17-156-23814	N 35 -,13.7	1		ISSR 08	25	80		100	337	ISSR 10	25	
Calibration, Polaroid	29 Nov 72	UU	40	AS17-156-23816	N 35 -,13.7	1/4		ISSR 08	26	80		100	337	ISSR 10	26	
Zodiacal Light, Red Filt	12 Dec 72 1523	XX	2	AS17-159-23905	N 35 55,1.2	90	21^h40^m-30	ISSR 08	27	80		332	458	ISSR 10	27	
Zodiacal Light, Red Filt	12 Dec 72 1527	XX	3	AS17-159-23906	N 35 55,1.2	60	21^h05^m-30	ISSR 08	28	80		332	458	ISSR 10	28	
Zodiacal Light, Red Filt	12 Dec 72 1532	XX	5	AS17-159-23908	N 35 55,1.2	40	19^h42^m-31	ISSR 08	29	80		332	458	ISSR 10	29	
Zodiacal Light, Red Filt	12 Dec 72 1534	XX	6	AS17-159-23909	N 35 55,1.2	20	19^h08^m-29	ISSR 08	30	80		332	458	ISSR 10	30	
Zodiacal Light, Red Filt	12 Dec 72 1535	XX	7	AS17-159-23910	N 35 55,1.2	10	18^h55^m-28	ISSR 08	31	80		332	458	ISSR 10	31	
Zodiacal Light, Red Filt	12 Dec 72 1536	XX	8	AS17-159-23911	N 35 55,1.2	6	18^h50^m-28	ISSR 08	32	80		332	458	ISSR 10	32	
Zodiacal Light, Red Filt	12 Dec 72 1536	XX	9	AS17-159-23912	N 35 55,1.2	2	18^h50^m-27	ISSR 08	33	80		332	458	ISSR 10	33	

PROCESSED FLIGHT AND CALIBRATION DATA FROM APOLLO 17 (Cont'd)

Subject	Date and GMT Time	Mg Dg	QL No	NASA Frame Number	Cam& Lens FL Frmt & f/No	Exp Tim	CntFrmLoc RtAsc Dec	Photodensitometry Digitization Data Tape Dg	Fi	Ap Sz	D M	Numb Line	Numb Samp	VICAR Format & Other Proc Tape Dg	Fi	C n
Zodiacal Light, Red Filt	12 Dec 72 1536	XX	10	AS17-159-23913	N 35 55,1.2	1/2	18^h50^m-26	ISSR 08	34	80		332	458	ISSR 10	34	
Zodiacal Light, Blue Flt	13 Dec 72 2206	XX	31	AS17-159-23934	N 35 55,1.2	90	21^h45^m-30	ISSR 08	35	80		332	458	ISSR 10	35	
Zodiacal Light, Blue Flt	13 Dec 72 2210	XX	32	AS17-159-23935	N 35 55,1.2	60	20^h50^m-30	ISSR 08	36	80		332	458	ISSR 10	36	
Zodiacal Light, Blue Flt	13 Dec 72 2213	XX	33	AS17-159-23936	N 35 55,1.2	60	20^h10^m-30	ISSR 08	37	80		332	458	ISSR 10	37	
Zodiacal Light, Blue Flt	13 Dec 72 2215	XX	34	AS17-159-23937	N 35 55,1.2	40	19^h45^m-30	ISSR 08	38	80		332	458	ISSR 10	38	
Zodiacal Light, Blue Flt	13 Dec 72 2216	XX	35	AS17-159-23938	N 35 55,1.2	20	19^h30^m-29	ISSR 08	39	80		332	458	ISSR 10	39	
Zodiacal Light, Blue Flt	13 Dec 72 2218	XX	36	AS17-159-23939	N 35 55,1.2	10	19^h15^m-29	ISSR 08	40	80		332	458	ISSR 10	40	
Zodiacal Light, Blue Flt	13 Dec 72 2218	XX	37	AS17-159-23940	N 35 55,1.2	6	19^h15^m-28	ISSR 08	41	80		332	458	ISSR 10	41	
Zodiacal Light, Blue Flt	13 Dec 72 2219	XX	38	AS17-159-23941	N 35 55,1.2	2	19^h10^m-28	ISSR 08	42	80		332	458	ISSR 10	42	
Zodiacal Light, Blue Flt	13 Dec 72 2219	XX	39	AS17-159-13942	N 35 55,1.2	1	19^h10^m-28	ISSR 08	43	80		332	458	ISSR 10	43	
Zodiacal Light, Blue Flt	13 Dec 72 2219	XX	40	AS17-159-23943	N 35 55,1.2	1/8	19^h00^m-27	ISSR 08	44	80		332	458	ISSR 10	44	
Zodiacal Light, Polaroid	14 Dec 72 1953	YY	8	AS17-160-23953	N 35 55,1.2	90	21^h45^m-12	ISSR 08	45	80		333	458	ISSR 14	1	
Zodiacal Light, Polaroid	14 Dec 72 1955	YY	9	AS17-160-23954	N 35 55,1.2	90	21^h15^m-15	ISSR 08	46	80		332	458	ISSR 14	2	
Zodiacal Light, Polaroid	14 Dec 72 1957	YY	10	AS17-160-23955	N 35 55,1.2	60	20^h50^m-18	ISSR 08	47	80		332	458	ISSR 14	3	
Zodiacal Light, Polaroid	14 Dec 72 1959	YY	11	AS17-160-23956	N 35 55,1.2	60	20^h35^m-18	ISSR 08	48	80		332	458	ISSR 14	4	
Zodiacal Light, Polaroid	14 Dec 72 2000	YY	12	AS17-160-23957	N 35 55,1.2	30	20^h15^m-19	ISSR 08	49	80		332	458	ISSR 14	5	
Zodiacal Light, Polaroid	14 Dec 72 2001	YY	13	AS17-160-23958	N 35 55,1.2	30	20^h05^m-20	ISSR 08	50	80		332	458	ISSR 14	6	
Zodiacal Light, Polaroid	14 Dec 72 2002	YY	14	AS17-160-23959	N 35 55,1.2	20	19^h50^m-21	ISSR 08	51	80		332	458	ISSR 14	7	
Zodiacal Light, Polaroid	14 Dec 72 2003	YY	15	AS17-160-23960	N 35 55,1.2	20	19^h45^m-20	ISSR 08	52	80		332	458	ISSR 14	8	
Zodiacal Light, Polaroid	14 Dec 72 2004	YY	16	AS17-160-23961	N 35 55,1.2	10	19^h35^m-21	ISSR 08	53	80		332	458	ISSR 14	9	
Zodiacal Light, Polaroid	14 Dec 72 2004	YY	17	AS17-160-23962	N 35 55,1.2	10	19^h25^m-21	ISSR 08	54	80		332	458	ISSR 14	10	
Zodiacal Light, Polaroid	14 Dec 72 2005	YY	18	AS17-160-23963	N 35 55,1.2	5	19^h15^m-21	ISSR 08	55	80		332	458	ISSR 14	11	
Zodiacal Light, Polaroid	14 Dec 72 2006	YY	19	AS17-160-23964	N 35 55,1.2	5	19^h15^m-21	ISSR 08	56	80		332	458	ISSR 14	12	
Zodiacal Light, Polaroid	14 Dec 72 2006	YY	20	AS17-160-23965	N 35 55,1.2	3	19^h10^m-21	ISSR 08	57	80		332	458	ISSR 14	13	
Zodiacal Light, Polaroid	14 Dec 72 2006	YY	21	AS17-160-23966	N 35 55,1.2	3	19^h10^m-21	ISSR 08	58	80		332	458	ISSR 14	14	
Zodiacal Light, Polaroid	14 Dec 72 2006	YY	22	AS17-160-23967	N 35 55,1.2	1	19^h05^m-21	ISSR 08	59	80		332	458	ISSR 14	15	
Zodiacal Light, Polaroid	14 Dec 72 2006	YY	23	AS17-160-23968	N 35 55,1.2	1	19^h00^m-21	ISSR 08	60	80		332	458	ISSR 14	16	
Zodiacal Light, Polaroid	14 Dec 72 2007	YY	24	AS17-160-23969	N 35 55,1.2	1/4	19^h00^m-21	ISSR 08	61	80		332	458	ISSR 14	17	
Zodiacal Light, Polaroid	14 Dec 72 2007	YY	25	AS17-160-23970	N 35 55,1.2	1/4	19^h00^m-21	ISSR 08	62	80		332	458	ISSR 14	18	
Calibration, ND2.0	29 Nov 72	ZZ	24	AS17-161-24021	N 35 -,13.7	300		ISSR 02	37	80		100	337	ISSR 14	19	
Calibration, ND2.0	29 Nov 72	ZZ	25	AS17-161-24022	N 35 -,13.7	180		ISSR 02	38	80		100	337	ISSR 14	20	
Calibration, ND2.0	29 Nov 72	ZZ	26	AS17-161-24023	N 35 -,13.7	60		ISSR 02	39	80		100	337	ISSR 14	21	

PROCESSED FLIGHT AND CALIBRATION DATA FROM APOLLO 17 (Cont'd)

Subject	Date and GMT Time	Mg Dg	QL No	NASA Frame Number	Cam& LensFL Frmt & f/No	Exp Tim	CntFrmLoc RtAsc Dec	Photodensitometry Digitization Data: Tape Dg	Fi	Ap Sz	D M	Numb Line	Numb Samp	VICAR Format & Other Proc: Tape Dg	Fi	C n
Calibration, No Filter	29 Nov 72	ZZ	27	AS17-161-24024	N 35 -,13.7	60		ISSR 02	40	80		100	337	ISSR 14	22	
Calibration, No Filter	29 Nov 72	ZZ	28	AS17-161-24025	N 35 -,13.7	20		ISSR 02	41	80		100	337	ISSR 14	23	
Calibration, No Filter	29 Nov 72	ZZ	29	AS17-161-24026	N 35 -,13.7	6		ISSR 02	42	80		100	337	ISSR 14	24	
Calibration, No Filter	29 Nov 72	ZZ	30	AS17-161-24027	N 35 -,13.7	2		ISSR 02	43	80		100	337	ISSR 14	25	
Calibration, No Filter	29 Nov 72	ZZ	31	AS17-161-24028	N 35 -,13.7	1		ISSR 02	44	80		100	337	ISSR 14	26	
Calibration, No Filter	29 Nov 72	ZZ	33	AS17-161-24030	N 35 -,13.7	1/4		ISSR 02	45	80		100	337	ISSR 14	27	

PROCESSED LENS VIGNETTING AND CALIBRATION DATA FOR CAMERAS USED ON APOLLOS 15, 16 AND 17

Subject	Cam& Frmt	LensFL & f/No	Exp Tim	Photodensitometry Digitization Data Tape	Dg	Fi	Ap Sz	D M	Numb Line	Numb Samp	VICAR Format & Other Proc Tape	Dg	Fi	C n	Remarks
AS 16 Vignetting	N 35	55,1.2	30	S211	04	1	40	X	800	1143	S211	24	3	X	
AS 16 Vignetting, Blue Filter	N 35	55,1.2	120	S211	04	2	40	X	800	1143	S211	24	1		
AS 16 Vignetting, Red Filter	N 35	55,1.2	60	S211	04	3	40	X	800	1143	S211	24	2		
AS 17 Vign. Calib.	N 35	55,1.2		S211	30	1	80				S211	29	6		
AS 17 Vign. Calib.	N 35	55,1.2		S211	30	2	80				S211	29	7		
AS 17 Vign. Calib.	N 35	55,1.2		S211	30	3	80				S211	29	8		
AS 17 Vign. Calib.	N 35	55,1.2		S211	30	4	80				S211	29	9		
AS 17 Vignetting	N 35	55,1.2	30	S211	30	6	80				S211	29	10		
AS 17 Vignetting	N 35	55,1.2		S211	30	7	80				S211	29	11		
AS 15 Vignetting	N 35	55,1.2		S211	39	1	40				S211	40	1		
AS 15 Vignetting	N 35	55,1.2	30	S211	39	2	40				S211	40	2	X	
AS 15 Vignetting	N 35	55,1.2		S211	39	3	40				S211	40	3		
AS 15 Vignetting	N 35	55,1.2		S211	39	4	40				S211	40	4		
AS 15 Vignetting	N 35	55,1.2	30	S211	39	5	40				S211	40	5	X	
AS 15 Vignetting	N 35	55,1.2		S211	39	6	40				S211	40	6		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	1	80				S211	42	1		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	2	80				S211	42	2		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	3	80				S211	42	3		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	4	80				S211	42	4		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	5	80				S211	42	5		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	6	80				S211	42	6		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	7	80				S211	42	7		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	8	80				S211	42	8		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	9	80				S211	42	9		
AS 15/16 Vign. Calib.	N 35	55,1.2		S211	41	10	80				S211	42	10		
AS 17 Vign. Calib.	N 35	55,1.2		S211	43	1	80				S211	44	1		
AS 17 Vign. Calib.	N 35	55,1.2		S211	43	2	80				S211	44	2		
AS 17 Vign. Calib.	N 35	55,1.2		S211	43	3	80				S211	44	3		
AS 17 Vign. Calib.	N 35	55,1.2		S211	43	4	80				S211	44	4		
AS 17 Vignetting	N 35	55,1.2		S211	43	5	80				S211	44	5		
AS 17 Vignetting	N 35	55,1.2		S211	43	6	80				S211	44	6		
AS 17 Vignetting	N 35	55,1.2		S211	43	7	80				S211	44	7		